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From the Library of the
Fogg Museum of Art
Harvard University

AN
EXPERIMENTAL INQUIRY
INTO THE
CAUSE of the CHANGES of COLOURS
IN
OPAKE AND COLOURED BODIES.

WITH AN

HISTORICAL PREFACE

Relative to the Parts of Philoſophy therein examined, and to the
ſeveral Arts and Manufactures dependent on them.

BY

EDWARD HUSSEY DELAVAL, F. R. S.

ΠΡΟΣΕΞΕΥΡΕΙΝ, ΚΑΙ ΠΑΡΑΔΟΥΝΑΙ ΤΟΙΣ ΤΕ ΤΑΣ ΤΕΧΝΑΣ ΕΡΓΑΖΟΜΕΝΟΙΣ, ΚΑΙ ΤΟΙΣ ΑΛΛΟΙΣ ΑΠΑΣΙΝ ΑΝΘΡΩΠΟΙΣ.

Diodor. Sicul. L. [illegible]

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THE
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IT appears to be extremely worth the Time and Pains of Philoſophers to inquire into the Orders of the Colours of natural Bodies, in the Manner propoſed and begun by Sir Iſaac Newton; and particulary to compare the Changes of Colour, which turn up in chemical Operations, with the other Changes, which happen to the Subjects of the Operations, at the ſame time. Nothing ſeems more likely than this to be a Key to the Philoſophy of the ſmall Parts of natural Bodies, and of their mutual Influences.

Hartley's Obſerva. C. 2. Sect. 4. Prop. 60.

PREFACE.

THE Subject of the following Work was ſuggeſted to the Author, by a cloſe attention to thoſe Experiments of Sir Iſaac Newton, which ſhew that *Colours* are exhibited by very thin plates of *pellucid Media:* and it is intended, as a kind of Supplement, to commence at that ſtate of the Inquiry, in which it was left by that great Philoſopher.

The Subſtances which he employed in making his optical Experiments, were *tranſparent* and *colourleſs:* ſuch as Glaſs, Water, and Air. And having diminiſhed, or increaſed, the thickneſs of thoſe ſubſtances by *mechanical* means, he produced, according to the different magnitudes of the pellucid Media, Differences or Changes of Colour.

The Colours, however, exhibited in thoſe Experiments, from their tranſient and temporary nature, were, I perceived, incapable of being applied to practical Uſes. In proportion, therefore, as I admired the greatneſs of thoſe Diſcoveries, I regretted that they were hitherto confined within the bounds of mere ſpeculative Knowledge, or philoſophical Curioſity; eſpecially as I imagined that, by a *practical* Application of the Theory, many uſeful Arts might be conſiderably improved.

Induced by theſe conſiderations, I endeavoured, by a ſeries of Experiments and Obſervations, to inquire into the Changes of Colour effected in *permanently coloured* Bodies, and to examine whether thoſe Changes are ſubject to the ſame Law which prevails in *colourleſs* Subſtances.

But becauſe *permanently coloured* Subſtances are, on account of their Opacity, generally diſqualified from tranſmitting the incident Light, and becauſe their diſpoſition to reflect only one particular Colour, renders them incapable of exhibiting any other, I was aware that the *mechanical* methods, by which the Colours of *pellucid* Media were altered, could not be effectually employed for producing ſuch Changes in *permanently coloured* Subſtances, while they remain in their entire ſtate: and therefore I found it expedient to have recourſe to ſuch *chymical Operations*

Operations as would *diminiſh or increaſe the Size* of the component parts of thoſe Subſtances, by ſeparating them into ſmaller, or uniting them into larger, Maſſes. For almoſt all the Changes which natural Bodies undergo, appear to ariſe from the Diviſion or Reunion of their component Particles: And, indeed, the Chymiſts have reduced the whole of their Art to theſe two Operations.

Hence Sir Iſaac Newton, at the cloſe of his Optics, lays down the following moſt excellent Doctrine: "All theſe things being conſidered, *it ſeems* "*probable to me,* that God in the beginning formed "Matter in ſolid, maſſy, hard, impenetrable, move-"able particles, of ſuch Sizes and Figures, and with "ſuch other Properties, and in ſuch Proportion to "Space, as moſt conduced to the End for which "he formed them; and that theſe primitive Par-"ticles being Solids, are incomparably harder than "any porous Bodies compounded of them; even ſo "hard, as never to wear or break in pieces: No or-"dinary Power being able to divide what God him-"ſelf made one in the firſt Creation. While the "Particles continue entire, they may compoſe Bo-"dies of one and the ſame Nature and Texture in "all Ages: But ſhould they wear away, or break

“ in pieces, the Nature of Things depending upon “ them, would be changed. Water and Earth, “ compoſed of old worn Particles and Fragments of “ Particles, would not be of the ſame Nature and “ Texture now, with Water and Earth compoſed of “ entire Particles, in the Beginning. And therefore, “ that Nature may be laſting, the Changes of cor- “ poreal Things are to be placed only in the various “ Separations and new Aſſociations and Motions of “ theſe permanent Particles; compound Bodies be- “ ing apt to break, not in the midſt of ſolid Parti- “ cles, but where thoſe Particles are laid together, “ and only touch in a few Points.”

In this paſſage the Doctrine of the Diviſion and Reunion of Particles of Matter, which compoſe natural Bodies, is clearly laid down, and beautifully illuſtrated: which Diviſion and Reunion are eſſential to thoſe effects of Chymiſtry and Optics, which are examined in the following Work.

But although this great Philoſopher, from the Manner of expreſſing himſelf here, ſeems to conſider this Truth, concerning the Permanency of the component Particles of Bodies, as his own original Diſcovery; yet it is certain that Opinions, which exactly coincide with his, were entertained by the moſt antient Philoſophers. Leucippus and Democritus held that "Bodies were compoſed of "Atoms, or very ſmall Particles, which, from their "Solidity, are incapable of being deſtroyed[a]." The latter Philoſophers of Greece borrowed theſe Doctrines of Leucippus and Democritus, and inculcated them[b]: And we find that they ſupported them by Arguments

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[a] Εἶναι γὰρ ϗ ταῦτα ἐξ ἀτόμων τινῶν συστήματα· ἅπερ εἶναι ἀπαθῆ ϗ ἀναλοίωτα διὰ τὴν στεῤῥότητα, Diog. Laert. l. ix. Segm. 44.

[b] Καὶ μὴν ϗ τὰς ἀτόμους νομιστέον, μηδεμίαν ποιότητα τῶν φαινομένων προσφέρεσθαι, πλὴν σχήματος, ϗ βάρους, ϗ μεγέθους, ϗ ὅσα ἐξ ἀνάγκης σχήματος συμφυῆ ἐστι· ποιότης γὰρ πᾶσα μεταβάλλει· αἱ δὲ ἄτομοι, οὐδὲν μεταβάλλουσιν· Ἐπειδήπερ δεῖ τι ὑπομένειν ἐν ταῖς διαλύσεσι τῶν συγκρίσεων στερεὸν ϗ ἀδιάλυτον.

Ὅθεν ἀναγκαῖον τὰ μὴ μετατιθέμενα ἄφθαρτα εἶναι, ϗ τὴν τοῦ μεταβάλλοντος φύσιν οὐκ ἔχοντα, ὄγκους δὲ ϗ σχηματισμοὺς ἰδίους. Τοῦτο γὰρ ϗ ἀναγκαῖον ὑπομένειν. Ejuſd. l. x. Segm. 54.

Τῶν σωμάτων τὰ μέν ἐστι συγκρίσεις, τὰ δ' ἐξ ὧν αἱ συγκρίσεις πεποίηνται. Ταῦτα δέ ἐστιν ἄτομα ϗ ἀμετάβλητα, εἴπερ μὴ μέλλει πάντα εἰς τὸ μὴ ὂν φθαρήσεσθαι· ἀλλ' ἰσχύοντα ὑπομένειν, ἐν ταῖς διαλύσεσι τῶν συγκρίσεων, πλήρη τὴν φύσιν ὄντα, ϗ οὐκ ἔχοντα ὅπῃ ἢ ὅπως διαλυθήσεται. Ὥστε τὰς ἀρχὰς, ἀτόμους ἀναγκαῖον εἶναι σωμάτων φύσεις. Ib. Segm. 41.

Many ſimilar paſſages might be adduced from the Author here cited, and from others. The learned Marſham, ſumming up the opinions which the antient Philoſophers entertained on this ſubject, attributes to them an argument, ſimilar to that by which Sir Iſaac Newton proves the indeſtructibility of the primary parts of material ſubſtances, Arguments ſimilar to thoſe which are uſed by Sir Iſaac Newton. Lucretius, who has given us the ſubſtance of that Philoſophy which was introduced into Greece by Democritus, has elegantly delivered ſome of theſe Opinions in the following lines, as well as in various other paſſages:

omnia quando
Paulatim creſcunt, ut par eſt, *ſemine certo:*
Creſcendoque *genus ſervant*; ut noſcere poſſis
Quæque ſuâ de materiâ grandeſcere, alique.
Lucret. l. i. 189.

The argument, in particular, which is by Newton deduced from the Immutability of Water, and other material ſubſtances, is uſed by this Poet:

Unde mare, ingenui fontes, externaque longè
Flumina ſuppeditant? unde æther ſidera paſcit?
Omnia enim debet, mortali corpore quæ ſunt,
Infinita ætas conſumpſe anteacta dieſque.
Quod ſi in eo ſpatio, atque anteactâ ætate fuere,
E quibus hæc rerum conſiſtit ſumma refecta,
Immortali ſunt naturâ prædita certe. Ib. 231.

Cicero,

ſubſtances, from the immutability of the Bodies themſelves: "Nam "ſi interitus rerum mutationi accederet, Univerſi tandem abolitio "ſequeretur, neque ſuppeteret, unde res renaſcerentur."
Marſham. Canon. Chron. Secul. XI. § 2.

Cicero[c], who alſo drew his Philoſophy from Greece, aſcribes the Permanency of terreſtrial Bodies to the agency of the Deity, coinciding with the ſentiments which our illuſtrious Author has delivered, in that part of his Optics, which is before-cited. Thus were the latter, as well as antient Greeks, acquainted with theſe and other philoſophical Truths.

Notwithſtanding this, it is alſo certain that the Philoſophers of Greece were not the original Diſcoverers of theſe truths; for it appears from the accounts delivered down to us, that their phyſical knowledge was confined to bare Properties and Effects, of which the Cauſes were unknown to them: They contented themſelves with dogmatical Aſſertions, concerning the Phænomena of Nature, unſupported by the Evidence of Experiment; without which means of Enquiry, it is certain that true Phyſical Knowledge can not be arrived at. Thus their Syſtems, corrupted by ideal Speculation, were erroneous and imperfect. For there aroſe among them various Sects, each excluſively holding Doctrines which, though falſe or deficient as ſeparately maintained, would, if united, have been conſonant to the Laws of Nature [d].

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[c] Talis igitur mens mundi cum ſit, ob eamque cauſam vel *prudentia*, vel *providentia* appellari rectè ſolet (Græce enim πρόνοια dicitur) hæc potiſſimùm *providet*, et in his maximè eſt occupata, primum ut mundus quam aptiſſimus ſit ad permanendum.

Cicero de Natura Deor. l. ii. XXII.

Hence it is that, amongſt the antient Writers of that Nation, we meet with few or no original Diſcoveries or Improvements, either in Natural Philoſophy, or in the Arts dependent on it.

Since, therefore, the Greeks were unacquainted with experimental Philoſophy, and employed none of thoſe Means through which a Proficiency in Phyſicks can be obtained, it is evident they muſt have acquired their Doctrines at an eaſier rate, by receiving them from Philoſophers of other Nations, who had doubtleſs, by their own proper Skill and Induſtry, diſcovered them.

And indeed Hiſtorians affirm that Democritus received the Doctrines which he introduced into

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[d] Thus Water was held by ſome to be the only Element, out of which all things were formed, whilſt others attributed their Formation to Earth, or to Air. But Chymical Analyſis has ſhewn, that all thoſe Principles are moſt frequently united in the Compoſition of natural Bodies.

Greece from the Philoſophers of India, Ethiopia, and Egypt, as well as from the Magi and Chaldeans, into whoſe Countries he travelled to inquire into their Learning [e].

For the Indians and Ethiopians were conſidered as the moſt Philoſophical of all Nations [f]. Strabo informs us, that, in India, Philoſophers were held in the greateſt eſteem, and that ſome of them were employed in phyſical Inquiries [g]. And this agrees with the Account which Diodorus Siculus had given of them; for from this writer we learn that their Philoſophers formed the firſt order in the State [h],

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[e] Περὶ Δημοκρίτου.—Ηκεν οὖν ϗ πρὸς τοὺς Χαλδαίους εἰς Βαβυλῶνα, ϗ πρὸς τοὺς Μάγους, ϗ τοὺς Σοφιστὰς τῶν Ινδῶν. Ælian. Var. Hiſt. l. iv. c. xx.

Φησὶ δὲ—ἀποδημῆσαι αὐτὸν ϗ εἰς Αἴγυπτον—ϗ πρὸς Χαλδαίους, εἰς τὴν Περσίδα, ϗ εἰς τὴν ἐρυθρὰν θάλασσαν γενέσθαι. Τοῖς τε γυμνοσοφισταῖς φασί τινες συμμίξαι αὐτὸν ἐν Ινδίᾳ, ϗ εἰς Αἰθιοπίαν ἐλθεῖν.

Diog. Laert. Δημόκρ. l. ix. ſegm. xxxv.

Δημόκριτος—ἐπῆλθε γὰρ Βαβυλῶνά τε ϗ Περσίδα ϗ Αἴγυπτον τοῖς τε Μάγοις ϗ τοῖς ἱερεῦσι μαθητεύων. Clem. Alex. Strom. lib. i. p. 222. Edit. Heinſii.

[f] Σοφώτατοι μὲν ἀνθρώπων Ινδοὶ, ἄποικοι δὲ Ινδῶν Αἰθίοπες, πατρῴζουσι δὲ οὗτοι τὴν σοφίαν. Philoſtrat. l. vi. c. xvi.

Ινδῶν δὲ ἡ φιλοσοφία ϗ αὐτῶν διαβεβόηται. Clem. Alex. Strom. l. vi. p. 457.

[g] Φησὶ δὲ τὸ τῶν Ινδῶν πλῆθος εἰς ἑπτὰ μέρη διῃρῆσθαι, ϗ πρώτους μὲν τοὺς φιλοσόφους εἶναι κατὰ τιμὴν, ἐλαχίστους δὲ κατ᾽ ἀριθμόν. Strabo, l. xv. p. 703.

Τοὺς δ᾽ ἄλλους (Βραχμᾶνας) σκοπεῖν τὰ περὶ τὴν φύσιν. Ib. p. 716.

[h] Diodor. Sicul. l. ii. p. 88.

and he relates ſeveral inſtances of their Skill in Natural Philoſophy. Megaſthenes expreſly aſſures us that all the Doctrines of Phyſicks were cultivated by the Brachmans of India, previous to their Introduction into Greece [i].

The Sages of Egypt alſo boaſted of being the firſt Cultivators of Philoſophy [k]. Herodotus, who had viſited that people, acknowledges that Greece borrowed much of its Learning from them [l]. And Diodorus Siculus, in a Chapter expreſly treating of thoſe Grecians who, in antient times, reſorted to Egypt for the ſake of learning the Sciences there cultivated, informs us that Democritus reſided in that Country five years for this purpoſe [m].

The ſacred Writers, as well as the later Hiſtorians, abound in teſtimonies of the Wiſdom and

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[i] Φανερώτατα δὲ Μεγασθένης ὁ συγγραφεὺς, ὁ Σελεύκῳ τῷ Νικάτορι συμβεβιωκὼς, ἐν τῇ τρίτῃ τῶν Ἰνδικῶν ὧδε γράφει. Ἅπαντα μέν τοι τὰ περὶ φύσεως εἰρημένα παρὰ τοῖς ἀρχαίοις, λέγεται ϗ παρὰ τοῖς ἔξω τῆς Ἑλλάδος φιλοσοφοῦσι τὰ μὲν, παρ' Ἰνδοῖς ὑπὸ τῶν Βραχμάνων. Clem. Alex. Strom. l. i. p. 224.

[k] Οἱ δὲ Θηβαῖοι φασὶν ἑαυτοὺς ἀρχαιοτάτους εἶναι πάντων ἀνθρώπων, ϗ παρ' ἑαυτοῖς πρώτοις φιλοσοφίαν τε εὑρῆσθαι. Diodor. Sicul. l. i. p. 32.

[l] Herod. l. ii. paſſim.

[m] Diodor. Sicul. l. i. p. 62.

Philoſophy of the Egyptians: but theſe are ſo well known, that it is not neceſſary to inſtance them in this place.

On this ſubject, however, it may not be improper to obſerve, that the principal Divinity of Egypt ISIS (by the Greeks called ΔΗΜΗΤΗΡ, and by the Romans CERES) repreſented Nature[n]; and that, in the greater Myſteries of that Goddeſs, the Phænomena of Nature were exhibited and explained[o]. And we learn from Seneca that ſeveral leſſons were neceſſary for the inſtruction of the initiated, from the copiouſneſs of the ſubject[p].

Nor were the Magi leſs diſtinguiſhed for their proficiency in the Knowledge of Nature, according to the accounts of many antient Authors, amongſt whom

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[n] Ἡ γὰρ Ἰσίς ἐςὶ μὲν τὸ τῆς φύσεως θῆλυ, ϗ δεκτικὸν ἁπάσης γενέσεως. Plutarch de Iſide, p. 372.

Στολαὶ αἱ μὲν Ἴσιδος ποικίλαι ταῖς βαφαῖς· περὶ γὰρ Ὕλην ἡ δύναμις αὐτῆς, πάντα γινομένην ϗ δεχομένην. Ib. p. 382.

[o] Μετὰ ταῦτα δ' ἐςὶ τὰ μικρὰ μυςήρια, διδασκαλίας τινὰ ὑπόθεσιν ἔχοντα ϗ προπαρασκευῆς τῶν μελλόντων. τὰ δὲ μεγάλα, περὶ τῶν Συμπάντων, οὐ μανθάνειν ἔτι ἀπολείπεται, ἐποπτεύειν δὲ, ϗ περινοεῖν τήν τε ΦΥΣΙΝ ΚΑΙ ΤΑ ΠΡΑΓΜΑΤΑ. Clem. Alex. l. v. p. 424.

[p] Eleuſis ſervat quod oſtendat reviſentibus: Rerum Natura ſua non ſimul tradit. Seneca. Nat. Quæſt. l. vii. c. xxxi.

Cicero atteſts their excellence in Science, and concurs with thoſe we have already cited, in relating that Democritus reſorted to Perſia, to procure from theſe great Maſters inſtruction in phyſical Inquiries[q].

The Chaldeans alſo cultivated Philoſphy with much ſucceſs, and they are ſaid to have employed all their lives in purſuit of this Study[r]. The moſt learned Writer of the preſent age has ſhewn that almoſt all the Sciences antiently originated from them[s]. And it is remarkable that the Permanency of Matter, and of the World which is compoſed of it, was maintained by thoſe Sages[t], according to the principles inculcated by Democritus.

But, tho' Greece thus borrowed its Philoſophy from the Nations of the Eaſt, at an early period of

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[q] Cur ipſe Pythagoras & Ægyptum luſtravit, & Perſarum Magos adiit? Cur tantas regiones barbarorum pedibus obiit? tot maria tranſmiſit? cur hæc eadem Democritus?—quid quærens aliud, niſi beatam vitam? quam ſi etiam in Rerum cognitione ponebat, tamen ex illa Inveſtigatione Naturæ conſequi volebat, ut eſſet bono animo.
Cicero de Finibus, l. 5. XXIX.

[r] Χαλδαῖοι—πάντα τὸν τοῦ ζῆν χρόνον φιλοσοφοῦσι. Diod. Sicul. l. ii. p. 81.

[s] Bryant. Syſt. Ant. Mythol. paſſim.

[t] Οἱ δ' ἐν Χαλδαίοι τὴν μὲν τοῦ κόσμου φύσιν ἀΐδιον φασὶν εἶναι.
Diodor. Sicul. l. ii. p. 82.

Hiſtory, I am, from ſeveral circumſtances, ſtrongly induced to believe that it flouriſhed in thoſe Eaſtern Nations at a Period much antecedent to its introduction into that Country; and, particularly, that Chymiſtry, by which alone the compoſition of Natural Bodies could have been diſcovered, was confined to, and ſolely cultivated in, Aſia, and the Eaſtern parts of Africa; unleſs Metallurgy, which includes but a ſmall part of Chymiſtry (and which, from its neceſſity, ſeems to have been very early exerciſed in almoſt all nations) be confounded with Chymiſtry in general.—My reaſons for this opinion are theſe:

1. Becauſe certain Arts dependent on chymical proceſſes were antiently practiſed in the Eaſt, altho' unknown in Greece, and all other parts of Europe.

2. Becauſe the ſame Oriental Nations continue to excel in thoſe Arts, many of which are in vain attempted, even at preſent, to be imitated by European Nations.

3. Becauſe the firſt Books, which treat of Chymiſtry as a Science, and which, notwithſtanding their early date, afford a good account both of its ſpecu-

lative and practical parts, are delivered to us from Writers of the Eaſt.

Before I mention the particular Arts dependent on Chymiſtry, the origin of which I attribute to the Oriental Nations, it may be proper to obviate an objection which may be made to the Novelty of this Inquiry. It may poſſibly be aſked, if ſuch Arts were practiſed antiently by thoſe Nations, whence is it that moſt of the circumſtances, which are here obſerved relative to them, have hitherto paſſed unnoticed? To this I anſwer, that, in theſe Reſearches, I have frequently remarked with regret, that although ſeveral perſons, eminent for their Learning, have tranſlated, or commented upon, the Works of the antient Writers on ſuch ſubjects, theſe modern Authors have not joined, to their great Erudition, a Knowledge of Natural Philoſophy, or of the Arts dependent upon it. From this Defect, the Connection between the Arts themſelves and the Parts of Natural Philoſophy, into which I have inquired, has hitherto paſſed almoſt unobſerved.

I ſhall, however, ſelect from among thoſe which flouriſhed at a very remote Period of Hiſtory in the

Eaſt, ſuch Arts only as relate to the practical Application of colouring Subſtances: and hence endeavour to trace the Origin and Hiſtory of Chymiſtry, and of Colours; from the Union of which two Subjects the following Work is formed.

The firſt I ſhall inſtance, is the Art of Dying. None of the Arts more abſolutely require the aſſiſtance of Chymiſtry than this: For though a few ſimple Colours may be accidentally diſcovered, and afterwards applied, without much ſkill; yet a more perfect Execution of this ingenious Trade, depends upon a proper management of Acids, Alcalies, various Salts, Metals, and other Subſtances, which cannot be produced, or acted upon, but by chymical Proceſſes, ſo as to be applied to any of the finer and more difficult Works.

In this Art it is certain the Oriental Nations antiently excelled; and from hence ſeveral parts of the Eaſt produced the ſame kinds of merchandize, which we now receive from them in our traffic. Which affords us one inſtance, among many, of the Effect that a fixed and invariable ſtate of Manners and Cuſtoms, ſo often obſerved in thoſe Countries, has had on their Manufactures and Commerce.

To the aid of Chymiſtry we muſt, in the firſt place, aſcribe that particular ſpecies of Dying, by which Linen or Cotton Clothes are painted, or printed, with Colours. Which Art, as antiently practiſed in various Eaſtern Countries, ſeems much to have reſembled the preſent ſtate of it amongſt the ſame Nations, from whom we now import Clothes thus manufactured. And it will appear from the following Obſervations, and from the paſſages which I have here collected from antient Writers, that the ſeveral countries, which were celebrated for theſe curious Works, produced alſo Linen, or Cotton, and dying materials for the manufacture of them.

This ſpecies of Dying was antiently cultivated in India, where it flouriſhed conſiderably: and that Country not only furniſhed Clothes, tinged with variouſly coloured Figures and Flowers, for the uſe of its own inhabitants; but alſo ſupplied other nations with them, as an article of Commerce.

Claudian alludes to theſe productions of India, in the following lines:

" Jam cochleis homines junctos, & quidquid inane
" Nutrit, in Attalicis quæ pingitur India velis [a].

Indeed, that Poet had juſt reaſon to blame the Taſte, in which ſuch Clothes were painted, if we may judge of the antient Workmanſhip by the modern: for it is certain, that, at this day, their Deſign is unequal to the beauty and richneſs of their Colouring.

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[a] Claudian in Eutrop. l. i. lin. 356.

From the great number of different Epithets, applied to the word *Velis* in the ſeveral Editions of Claudian, I am inclined to think that the original Adjective has been loſt, and has been arbitrarily ſupplied by the Editors. From among the words Lydiacis, Indiacis, Niliacis, Attalicis, &c. I have choſen the laſt, as it ſeems leſs than the others to riſk vitiating the ſenſe of the paſſage. For, I believe Attalicus is generally uſed, merely to ſignify rich, elegant, or fine, ſuch as was poſſeſſed by Attalus, king of Pergamus, who was famous for his wealth and magnificence. Heinſius propoſes for the word *Velis* to ſubſtitute *Telis*, meaning Tapeſtry or Carpets in which the colours are interwoven. But it appears from Pliny, l. xix. c. i. and from the conſtant uſage of other authors, that Velum was a term applied to Linen, and more eſpecially ſo when dyed: and it is thus uſed in a paſſage hereafter cited, relative to the exerciſe of this kind of Dying in Egypt.

Strabo relates that the Indians wore *flowered Linens* ΣΙΝΔΟΝΑΣ ΕΥΑΝΘΕΙΣ, and, from the Epithet it appears that thoſe Ornaments were finely executed [w].

From the ſame Nation, the method of dying Linen of various Colours was firſt learned by the Macedonians, who accompanied Alexander on an expedition to the river Indus [x].

Many circumſtances are to be found in Hiſtorians relative to the Culture, Manufacture, and Uſe of Linen and Cotton in that Country, on which the Colours, alſo produced there, were employed.

Flax was cultivated in India [y], and we are informed

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[w] Strabo, l. xv. p. 709.——Sindon ſignifies Linen, or linen Garments.——Heſychius. Σινδὼν, ὀθόνη.—Ὀθόνια, λινᾶ ἱμάτια.——Bayfius de re veſtiaria, p. 53, Sindon, Veſtis linea. By the ſame word. Cotton Clothes are ſometimes expreſſed.

[x] Tentatum eſt *tingi Linum* quoque, & *veſtium inſaniam* accipere; in Alexandri Magni *primum* claſſibus, Indo amne navigantis, cum duces ejus & præfecti in certamine quodam variaſſent inſignia navium, ſtupueruntque littora flatu verſicoloria implente.
Plinii, l. xix. c. i.

[y] Terra (Indiæ) Lini ferax, inde pleriſque ſunt veſtes.
Q. Curtii, l. viii. c. ix.

formed of the Seaſon and Soil which was there eſteemed proper for ſowing that plant[z].

The peculiar Skill of this People, in ſpinning and weaving Linen, was alſo very conſpicuous, inſomuch that Dionyſius Periegetes, deſcribing their manners and cuſtoms, mentions their employment in ſuch Works as a diſtinguiſhing national occupation[a].

A part of their Dreſs conſiſted of linen cloth, thus prepared by them[b]: and we find that it formed an extenſive branch of their Commerce. The Author of the Periplus maris Erythræi enumerates many Indian Marts which traded in this Merchandize,

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[z] Ἐκ δὲ τῆς ἀναθυμιάσεως τῶν τοσούτων ποταμῶν, ϗ ἐκ τῶν ἐτησίων, ὡς Ἐρατοσθένης φησὶ, βρέχεται τοῖς θερινοῖς ὄμβροις ἡ Ἰνδικὴ, ϗ λιμνάζει τὰ πεδία· ἐν μὲν οὖν τούτοις τοῖς ὄμβροις λῖνον σπείρεται· Strabo. l. xv. p. 690.

[a] Πρὸς δ' αὐγὰς Ἰνδῶν ἐρατεινὴ πέπταται αἶα,
——————Οἱ δ' ἱϛοὺς ὑφόωσι λινεργίας.
Dionyſ. Perieg. lin. 1116.

[b] Indi, corpora uſque ad pedes Carbaſo * velant: ſoleis pedes, capita *linteis* vinciunt. Q. Curtii, l. viii. c. ix.

* Ad eund. loc. Raderus. Carbaſus autem eſt tenuiſſimæ & delicatiſſimæ telæ ſeu Lini genus.

Στολὴν δὲ εἶναι τοῖς μετὰ τὸν Ἰνδὸν λίνου φασὶν ἐγχωρίου.
Philoſtrat. l. ii. c. xx.

dize[c], and of which the moſt famous was ſituated on the Ganges, and took its name from that river[d].

I thought it neceſſary to examine into theſe particulars, as ſome Writers have fallen into great errors concerniug them. Thus Voſſius, in his Annotations on Pomponius Mela, inſiſts that wherever the Antients mention the Woollen, Linen, or Cotton of India, we are to underſtand that, by thoſe words, they mean Silk. "Sic ſentio, ubi-"cunque apud Veteres aut lanæ, aut lini, aut byſſi "Indici mentio fit, intelligendum id eſſe de ſerico," ad Pomp. Melæ, l. iii. c. vii. an aſſertion very inconſiſtent with the accounts which I have here adduced from the beſt Authorities relative to this People; who, moreover, would not have admitted the general Uſe of Silk, if they had poſſeſſed it, from religious motives, which I ſhall explain hereafter.

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[c] Μητρόπολις δὲ τῆς χώρας Μινναγάρα, ἀφ᾽ ἧς ϗ πλεῖστον Ὀθόνιον, εἰς Βαρύγαζαν κατάγεται.—Arriani Periplus maris Eryth. Edit. Stuckii. Genevæ, 1677, p. 13.

Ὀζήνη—ἀφ᾽ ἧς πάντα τὰ πρὸς εὐθηνίαν τῆς χώρας, εἰς Βαρύγαζαν καταφέρεται, ϗ τὰ πρὸς ἐμπορίαν τὴν ἡμετέραν, ὀνυχίνη λιθία ϗ μουῤῥίνη, ϗ Σινδόνες Ἰνδικαὶ, ϗ μολόχιναι, ϗ ἱκανὸν χυδαῖον Ὀθόνιον. Ib. p. 15.

Φέρεται δὲ ἀπὸ τῶν τόπων Ὀθόνιον παντοῖον—ϗ Νῆμα, ϗ τὰ ἀπὸ τῶν ἐμπορίων φερόμενα. Ib. p. 16.

Ἀπὸ δὲ Ταγάρων, Ὀθόνιον πολὺ χυδαῖον, ϗ Σινδόνων παντοῖα. Ib.

Ταπροβανή—γίνεται δὲ ἐν αὐτῇ λιθία διαφανὴς, ϗ Σινδόνες. Ib. p. 19.

Μασαλία—γίνονται ἐν αὐτῇ Σινδόνες πλεῖσται. Ib.

[d] Ποταμὸς δέ ἐστιν περὶ αὐτὸν, ὁ Γάγγης λεγόμενος, ϗ αὐτὸς μέγιστος τῶν κατὰ τὴν Ἰνδικήν· καθ᾽ ὃν ϗ ἐμπόριόν ἐστιν ὁμώνυμον τῷ ποταμῷ, ὁ Γάγγης, δι᾽ οὗ φέρεται τό τε μαλάβαθρον, ϗ Σινδόνες αἱ διαφορώταται, αἱ Γαγγιτικαὶ λεγόμεναι. Ib.

From the moſt antient teſtimonies we alſo learn that Cotton was produced and wrought in this Country[e]. Pliny informs us that the fineſt Clothes were made from this Plant which grew there[f], as well as in Perſia[g]. Arrian commends theſe on account of their Whiteneſs[h]: And it does not appear that they differed from the Cottons which we now import from thence, and which are printed or painted with a variety of Figures, and Colours far exceeding thoſe which the Europeans have lately introduced in imitation of them. Theſe Manufactures are not executed by the Mahometans in India, but by the Deſcendents of its antient Inhabitants[i]; to which Race this Art of tinging Clothes with various Colours, as well as that of plain Dying, ſeems to have been tranſmitted by their Anceſtors.

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[e] Τὰ δὲ δένδρεα τὰ ἄγρια αὐτόθι φέρει καρπὸν εἴρια καλλονῇ τε προφέροντα, ϗ ἀρετῇ τῇ ἀπὸ τῶν ὀΐων· ϗ ἐσθῆτι οἱ Ἰνδοὶ ἀπὸ τούτων τῶν δενδρέων χρέωνται.
Herodot. l. iii. cvi.

Καὶ τῶν ἐριοφόρων δένδρων φησὶν ξύλος τὸ ἄνθος ἔχειν πυρῆνα. ἐξαιρεθέντος δὲ τούτου, ξαίνεσθαι τὸ λοιπὸν ὁμοίως ταῖς ἐρέαις.
Strabo, l. xv. p. 694, de India.

[f] De Goſſampinis, & arboribus ex quibus Veſtes fiunt.—Arbores vocant goſſampinos, fertiliores etiam Tylo in minore, quæ diſtat XM. paſ. Juba circa fruticem lanugines eſſe tradit, linteaque fieri Indicis præſtantiora.—Sic Indos ſuæ arbores veſtiunt.
Plinii, l. xii. cxi.

[g] De arboribus Perſicæ Inſulæ, & lanigeris arboribus.—Ferunt Cotonei mali amplitudine cucurbitas, quæ maturitate ruptæ oſtendunt lanuginis pilas, ex quibus veſtes pretioſo linteo faciunt. Ib. c. x.

[h] Ἐσθῆτι δὲ Ἰνδοὶ λινέῃ χρέονται, κατάπερ λέγει Νέαρχος, λίνου τοῦ ἀπὸ τῶν δενδρέων, ὑπὲρ ὅτευ μοι ἤδη λέλεκται. τὸ δὲ λίνον τοῦτο, ἢ λαμπρότερον τὴν χροιὴν

As this country was diſtinguiſhed for ſuch Works, ſo we find that it ſupplied the Materials requiſite for their execution. Accordingly we are aſſured by Strabo that it abounded in Drugs, Roots, and colouring Subſtances[k], and that from theſe ingredients *admimirable*

χροιὴν ἐστιν ἄλλου λίνου παντὸς· ἢ μέλανες αὐτοὶ ἐόντες λαμπρότερον τὸ λῖνον φαίνεσθαι ποιέουσιν. Arrian. Rerum Indicar. Edit. H. Stephan. 1675, p. 179.

[i] "Some of the reigning (Hindoo) princes trace their families, "with clearneſs, above four thouſand years.—Theſe countries, go"verned by native princes, which lay beyond the devaſtations of the "Mahomedans, are rich, and cultivated to the higheſt degree. "Their governors encourage induſtry and commerce; and it is to "the ingenuity of the Hindoos, we owe all the fine manufactures in "the Eaſt."—Dow. Hiſt. of Hindoſtan, p. xxxvi.

[k] Καὶ πολυφάρμακον δὴ, καὶ πολύῤῥιζον, ὥσπερ καὶ ΠΟΛΥΧΡΩΜΑΤΟΝ. Strabo, l. xv. p. 694, de India.

mirable Dyes were produced[l]. Pliny mentions ſome of them, which bear a ſtrong reſemblance, both in Name, and in Deſcription, to thoſe which we now receive from that part of the world. Among theſe is a Subſtance very ſimilar in its Name, Colour, and Origin to the Indigo[m], uſed by our Dyers, the beſt kinds of which grow in the Mogul's Empire.

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[l] Καὶ γὰρ δὴ φέρειν τὴν χώραν (Ἰνδικὴν) ΧΡΟΑΣ ΘΑΥΜΑΣΤΑΣ, ϗ θριξὶ, ϗ ΕΣΘΗΣΙ. τοὺς δ᾽ ἀνθρώπους τὰ ἄλλα μὲν εὐτελεῖς εἶναι, φιλοκόσμους δέ.
Strabo, l. xv. p. 699, de India.

[m] Ab hoc maxima autoritas *Indico.* Ex India venit harundinum ſpumæ adhæreſcente *limo*; cum teritur nigrum, at in diluendo mixturam purpuræ cæruleique mirabilem reddit. Plinii, l. xxxv. c. vi.

Indiâ conferente fluminum ſuorum limum. Ib. c. vii.

As the modern Indigo reſembles the dying Ingredient mentioned by Pliny, in its appellation, ſo likewiſe it appears to be the ſame in reſpect to Colour: being, when undiluted, ſo intenſely coloured as to appear black: while ſome kinds of it are more purple, and others bluer; each of them inclining to bluer or purpler hues, in proportion as they are more or leſs diluted. Our Indigo, in like manner, is ſimilar to that of Pliny in its Origin, for, as the Indigo of theſe modern times is a Mud or Fæcula, formed from the putrefaction of a Plant in Water; Pliny relates that the Indicum of the Antients was a Mud adhering to Plants in the Rivers of India: though, I think it is probable that, the Mud or Fæcula of which the antient Indicum conſiſted, was produced by the natural Decay of Vegetables, ſimilar to the Anil, in thoſe Rivers.

The red Reſin, called Dragons-blood, by the antient as well as modern Artiſts, was brought alſo from India[n].

Beſides theſe they appear to have uſed a purple and ſcarlet Dye, reſembling Cochineal in Colour, and in the manner of its production. Cteſias[o], and after him Ælian[p], give an account of the Inſects which yielded it, and of the Plants on which they fed. And much of it muſt have been produced in that Country, as large quantities were annually exported from thence[q]. From this material, it is probable, that they were ſupplied with that abundance of Purple, which enabled even the commoneſt

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[n] Plinii. l. xxxiii. c. vii.——Ib. l. xxxv. c. vii.

[o] Ἀυτόθι ἐςὶ γινόμενα θηρία τὸ μέγεθος ὅσον κάνθαρος, ἐρυθρὰ ὥσπερ κιννάβαρι. πόδας δὲ ἔχει μακροὺς σφόδρα. μαλακὸν δέ ἐςιν ὥσπερ σκώληξ. ϗ γίνεται ταῦτα ἐπὶ τῶν δένδρων τῶν τὸ ἤλεκτρον φερόντων· ϗ τὸν καρπὸν κατεσθίει ἀυτῶν ϗ διαφθείρει, ὥσπερ ἐν τοῖς Ἕλλησιν οἱ φθεῖρες τὰς αμπέλους. ταῦτα οὖν τὰ θηρία τρίβοντες οἱ Ἰνδοὶ, βάπτουσι τὰς φοινικίδας ϗ τους χιτῶνας, ϗ ἄλλο ὅ τι ἂν βούλωνται. καί εισι βελτίω τῶν παρὰ Πέρσαις βαμμάτων.
Ex Cteſiæ Indicis, XXI.

[p] Ælian de Nat. Animal. l. iv. c. xlvi.

[q] Ex Cteſiæ Indicis, XXI.—Ælian de Nat. Animal. l. iv. c. xlvi.

eſt people among them to wear Clothes of that Colour [r].

Many ingredients of the Materia Tinctoria, which are uſed by the Dyers in Europe, are at preſent imported from India.

That part of Aſia, which is ſituate between the Euxine and the Caſpian ſea, and which now is comprehended under the names of Georgia and Armenia, was alſo, from the earlieſt antiquity, celebrated for this Art of dying Clothes with various Forms and Colours. Herodotus, in his deſcription of the nations which inhabited Caucaſus, a mountain extending throughout this region [s], affirms that they adorned their Clothes with the Figures of Animals, by means of Vegetables, ground and diluted with water, from which the moſt durable Dyes were obtained.

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[r] Ἀλλὰ ϗ ἐν ὀλίγῃ πορφύρᾳ στιλβούσῃ ἐν ἱματίῳ ἐναβρύνεσθε μεγάλως, τῶν Ἰνδῶν ὁλοπορφύρων ὄντων, τῶν δούλων ὑμῶν ὁλοπόρφυρα φορούντων.
Palladius de Gent. Indiæ & de Bragman. p. 43.

[s] Ἔστι δ᾽ ὄρος τοῦτο (Καύκασος) ὑπερκείμενον τοῦ πελάγους ἑκατέρου, τοῦ τε Ποντικοῦ, ϗ τοῦ Κασπίου, διατειχίζον τὸν ἰσθμὸν, τὸν διείργοντα αὐτά.
Strabo, l. xi. p. 497.

tained[t]. Other Writers, who mention the ſame Work carried on by this people, do not confine the colouring matters to vegetables only[u].

It is remarkable that the Art, thus deſcribed by theſe Authors, continues ſtill to be practiſed in that Country[w], where, according to them, it flouriſhed in

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[t] Καὶ τὰ μὲν πρὸς τὴν ἑσπέρην φέροντα τῆς θαλάσσης ταύτης ὁ Καύκασος παρατείνει, ἐὼν ὀρέων ϗ πλήθει μέγιστος, ϗ μεγάθεϊ ὑψηλότατος. Ἔθνεα δὲ ἀνθρώπων πολλὰ ϗ παντοῖα ἐν ἑωϋτῷ ἔχει ὁ Καύκασος. * τὰ πολλὰ, πάντα ἐξ ὕλης ἀγρίης ζώοντα. ἐν τοῖσι ϗ δένδρεα φύλλα τοιῆσδε ἰδέης παρεχόμενα εἶναι λέγεται, τὰ τρίβοντάς τε ϗ παραμίσγοντας ὕδωρ, ζῷα ἑωϋτοῖσι ἐς τὴν ἐσθῆτα ἐγγράφειν. τὰ δὲ ζῷα οὐκ ἐκπλύνεσθαι, ἀλλὰ συγκαταγηράσκειν τῷ ἄλλῳ εἰρίῳ, κατάπερ ἐνυφανθέντα ἀρχήν. Herodot. l. i. cciii.

[u] Τὴν δ' ἐσθῆτα ποικίλλουσιν ἐπιχρίστοις φαρμάκοις, δυσεξίτηλον ἔχουσι τὸ ἄνθος. Strabo, l. xi. p. 513.

* Both Herodotus and Strabo further mark out this Country, by the mention of the river Araxes, which runs through a conſiderable part of it.

[w] Erzeron, Capitale de la partie de l'*Armenie*, qui appartient au Grand Seigneur.—La Garance qu' on y trouve en tres-grande quantité, y vient de Perſe. Elle ſert aux habitans d' Erzeron pour *la teinture de leur Toiles.*——Tocat eſt la ſeconde ville de l'*Armenie* Turc pour le negoce. *Les toiles peintes* ſont encore un grand objet de negoce. Il eſt vrai que celles de Tocat ne ſont pas ſi belles que celles de Perſe; mais les Muſcovites et les Tartares de la Crimée pour qui elles ſont deſtinées s'en contentent. Il en paſſe néanmoins quelques-unes en France; et ce ſont celles qu' on y appelle Toiles du Levant. Savary Dict. de Comm. Suppl. p. 640.

I

in the remoteſt times: eſpecially as the practice of it, from its difficulty, has been confined to only a ſmall number of places, famous for the production of the neceſſary materials, and for the Ingenuity of the inhabitants in applying them to this Uſe.

We find very early accounts of the Linen wrought in thoſe Parts, and it appears from them that the Colchi, a nation bordering on the Eaſtern end of the Euxine, traded with Greece in that merchandize; and that, from their employment in its Manufacture, which was alſo exerciſed by the Egyptians, both of them were judged to have derived their Origin from one common Source[x]. From the relations reſpecting

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I have not ſcrupled, amongſt other authorities, to cite this Work, which, though arranged in the form of a Dictionary, contains an authentic and extenſive account of the Traffick of the ſeveral Countries, of which the Writer was enabled to procure full information, from his office as Inſpector General in the department of Commerce in France.

[x] Φαίνονται μὲν γὰρ ἰόντες οἱ Κόλχοι Αἰγύπτιοι. νοήσας δὲ πρότερον αὐτὸς, ἢ ἀκούσας ἄλλων, λέγω.—αὐτὸς δε εἴκασα τῇδε, ϗ ὅτι——φέρε δὴ ϗ ἄλλο εἴπω περὶ τῶν Κόλχων, ὡς Αἰγυπτίοισι προσφερέες εἰσί. λῖνον μοῦνοι οὗτοί τε ϗ Αἰγύπτιοι ἐργάζονται κατὰ ταυτὰ. λῖνον δὲ τὸ μὲν Κολχικὸν ὑπὸ Ἑλλήνων Σαρδονικὸν κέκληται. Herodot. l. ii. cv.

Λινόν τε ποιεῖ πολὺ—ἡ δὲ λινουργία ϗ τεθρύλληται· ϗ γὰρ εἰς τοὺς ἔξω τόπους ἐπεκόμιζον· καί τινες βουλόμενοι συγγένειάν τινα τοῖς Κόλχοις πρὸς τοὺς Αἰγυπτίους ἐμφανίζειν, ἀπὸ τούτων πιστοῦνται. Strabo, l. xi. p. 498.

reſpecting the Indians, which I have here offered, I think it is apparent that they alſo may be ranked with thoſe two Nations, not only from a Similarity in their antient Works of Linen, but alſo from their excellence in the ſame ſpecies of Dying, and from the extenſive Commerce for which each of them was renowned.

This Region ſtill abounds in Flax: Mr. Tournefort obſerved large quantities of that Plant, growing in ſeveral parts of Armenia and Georgia [y]: although it is at preſent neglected by the inhabitants, who prefer the uſe of Cotton [z]. It is probable, indeed, that the Clothes of this Country, which were antiently died with various Colours and Figures, were ſuppoſed by Herodotus to have been made of the latter Vegetable: for the word EIPION is conſtantly ly applied by that Writer, and others, to ſignify Cotton: and the trees which bear that down are called ΕΡΙΟΦΟΡΑ; as in Latin, Lana and Lanigeræ are uſed in the ſame ſenſe[a].

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[y] Tournefort, Voyage du Levant, a Lyon, 1717, Lett. xviii. p. 151, Lett. xix. p. 192.

[z] Dans la Georgie,—On n' y mange, et on n' y brule que de l'huile de Lin; toutes les campagnes ſont couvertes de cette Plante; mais on ne la cultive que pour la graine; car on jette la tige ſans la battre pour la filer: quelle perte? on en feroit les plus belles toiles du monde: peutetre auſſi que ces toiles feroient grand tort à leur Commerce de toiles de Coton.
Tournefort V. du Lev. Lett. xviii. p. 174.

Xenophon, however, who had ſeen the People to whom this Art was aſcribed, obſerves that Linen was ſo much in uſe among them, that even their Soldiers wore Corſlets of that Cloth[b]. And Valerius Flaccus, whoſe chief excellence ſeems to conſiſt in characterizing thoſe nations, diſtinguiſhes a Warrior ſlain at Colchis, during the Argonautic expedition thither, by a painted garment; and at the ſame time ſpecifies that his dreſs was of fine white Linen[c].

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[a] See the Notes [e] and [g] p. 21 above.—The word Lana ſignifies any downy ſubſtance, as hair or feathers. So Lana leporina, lana anſerina.

[b] Ἐπορεύθησαν· διὰ Χαλύβων—Εἶχον δὲ θώρακας λινοῦς μέχρι τοῦ ἤτρου.
Xenoph. Anab. l. iv.

This nation of Chalybes (for there were many of that name) is placed by Xenophon between the Rivers Phaſis and Harpaſus, which ſituation anſwers to that of the Araxes, near its ſource.

[c] Tenuia non illum candentis carbaſa lini,
——pictoque juvant ſubtemine bracæ.
Val. Flacc. l. vi. lin. 226.

Dying materials were here plentifully produced. Colchis was famous for its fertility in Plants, and by their means Medea is feigned to have performed her Enchantments. Mithridates, whoſe Kingdom was contiguous to it, was greatly celebrated for his Skill in Botany [d]. The reſt of this Tract of land afforded, almoſt every where, a ſoil luxuriant in Vegetables [e]. I have already ſhewn that ſome of them were, in the earlieſt ages, employed in Dying. A modern Botaniſt, who viſited this country, and examined its Plants, confirms theſe accounts of their variety and abundance [f], and informs us that great quantities of them are ſtill uſed in the very ſame Species of Dying to which, according to the Authors whom I have cited, they were antiently applied. For, more than two thouſand Camel-loads of Madder are annually ſent from Georgia to Diurbek and India, where the fineſt Calicos are painted with it[g].

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[d] Plinii, l. xxv. c. vi.——Ib. c. x.

[e] Herbaſque quas Colchos * atque Iberia
Mittit.————

Horat. Epod. v.

* Al: Iolchos.

For the fertility of Iberia and Albania, now parts of Georgia, ſee Strabo, l. xi. p. 500—528.——
Πλησίον δὲ ϗ ὁ Ἀράξης ἐμβάλλει, τραχὺς ἐκ τῆς Ἀρμενίας ἐκπίπτων— οὐδὲ γὰρ τῇ γῇ χρῶνται κατ' ἀξίαν. πάντα μὲν γὰρ ἐκφέρουσι καρπὸν, ϗ τον ἡμερώτατον, πᾶν δὲ φυτὸν, ϗ γὰρ τὰ ἀειθαλῆ φέρει. τυγχάνει δ' ἐπιμελείας οὐδὲ μικρᾶς, &c. Ib. p. 502.

[f] On ne peut pas douter que ce ne ſoit un de ces quartiers de la Georgie ou, ſuivant Strabon, abondent toutes ſortes de fruits que la terre y produit ſans Culture.——Tout le pays eſt fertile en belles Plantes. Tournefort V. du Lev. Lett. xviii. p. 159.

Minerals, applicable to the ſame uſe, were alſo found here. Colchis furniſhed a red Subſtance, which was obtained from an inacceſſible Rock with great pains[h]. It ſeems to have been a ferruginous Earth, reſembling that of Sinope in Colour, and in its native ſtate[i]: and it was called by the ſame name which Theophraſtus and others give to the Terra Sinopica[k]. In ſuch Earths, as well as in other colouring matters, this region abounded, as well as the Euxine[l], which waſhes its coaſts. Armenia was formerly, as at preſent, diſtinguiſhed for its Bole, which is of a Red colour, inclining to Yellow. Theſe earths, from their impregnation with Iron, are extremely uſeful in Dying, and the moſt beautiful Colours are ſtill produced by them in the adjacent countries[m].

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[g] On Envoye tous les ans plus de deux mille charges de Chameaux, des environs de Teflis et du reſte de la Georgie, a Erzeron de la racine appellée Boïa *. D'Erzeron elle paſſe dans le Diurbequis, où l'on l'employe à *teindre des toiles* que l'on y fabrique pour la Pologne. La Georgie fournit auſſi beaucoup de la meme racine pour l'Indoſtan, où l'on fait *les plus belles toiles peintes.*
Tournefort V. du Lev. Lett. xviii. p. 170.

* Garance qu'ils appellent Boïa. Ib. p. 111.

[h] Γίνεται δὲ ϗ Κιννάβαρι—ϗ τό ἐν Κόλχοις. τοῦτο δέ φασὶν ἔιναι κρημνῶν. ἐνκαταβάλλουσι τοξέυοντες. Theophraſt. de lapid. ciii.

Minium reperiri—item ad Colchos in rupe quadam inacceſſa, ex qua jaculantes decuterent, id eſſe adulterum. Plinii, l. xxxiii. c. vii.

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[i] Sinopis inventa eſt primum in Ponto, inde nomen a Sinope urbe. *Quæ ſaxis adhæſit*, excellit.—Species Sinopidis tres, *rubra*, et minus rubens, et inter has media. Plinii, l. xxxv. c. vi.

[k] Plinii, l. xxxiii. c. vii.—Theophraſt. de lapid. xci. ciii.

[l] Τοῦ δὲ Πόντου καθαιρομένου, ἐπιφέρεταί τι κατὰ τὸν Ἑλλήσποντον, ὃ καλοῦσι φῦκος· ἔστι δὲ ὠχρὸν τοῦτο· οἱ δὲ φασι τοῦτο ἄνθος εἶναι τοῦ φύκου· ἀφ' οὗ τὸ φύκιον εἶναι.—Φασὶ δέ τινες τῶν θαλαττίων καὶ τὴν πορφύραν ἴσχειν ἀπὸ τούτου τὸ ἄνθος. Ariſtot. de Hiſt. Anim. l. vi. c. xiii.

[m] Les couleurs que les Teinturiers de Perſe donnent aux ſoyes, et aux autres matieres qu'ils emploient en étoffes, ſont plus vives et plus belles que celles des Teinturiers d'Europe.—Les drogues qu'ils employent pour leurs teintures ſont le *Bol rouge*, &c.
Savary, D. de Comm. vol. I. p. 1110.

To this abundance of colouring materials, and to the ſame of the manufactures carried on by their means, I attribute the ſeveral antient Traditions which I have met with, relative to the ſame ſubject in this part of Aſia. Thus, Medea was eſteemed the Inventreſs of a particular branch of the Art[n], and the Argonauts, on their return from her Father's dominions, were ſuppoſed to have acquired ſuch extraordinary Skill in it, that, according to Ariſtotle, even the Pebbles on the Shores, where they had paſſed, were believed to have been tinged by them[o]. The preſent inhabitants of Georgia continue to ſhew the moſt ſuperſtitious regard to the ſame Trade, and their Veneration for it has extended ſo far, as to have become a part of their Religion[p].

The manner, in which the Egyptians executed this Art, is particularly deſcribed by Pliny[q]: and

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[n] Μήδειά τε ἡ 'Αιήτου ἡ Κολχὶς, πρώτη βαφὴν τριχῶν ἐπινόησεν.
Clem. Alex. Strom. l. i. p. 225.

[o] Ariſtot. de Mirab. Auſcult. lib.

[p] Tournefort Voyage du Lev. Lett. xviii. p. 175.

[q] Pingunt & veſtes Ægypto inter pauca mirabili genere, candida vela poſtquam attrivere illinentes non Coloribus, ſed colorem ſorbentibus

we find, from his account, that the methods which were employed, required much Skill in Chymiſtry.

The white Cloth, after having been prepared by drawing on it with colourleſs Ingredients, was ſteeped in the dying Vat, which contained à Liquor of one equable and uniform Colour: Upon taking it out from thence, it appeared diverſified with various Dyes.

The Statues of Iſis were habited in ſuch party-coloured Clothes[r], which were doubtleſs of Linen or Cotton: for Woollen was ſo much abhorred by the Egyptians, that it was excluded from their Temples and Interments[s]. Their Averſion extended alſo to the Flocks, and the Shepherds who

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tibus medicamentis. Hoc cum fecere, non apparet in velis: ſed in cortinam pigmenti ferventis merſa, poſt momentum extrahuntur picta. Mirumque cum ſit unus in cortina colos, ex illo alius atque alius fit in veſte, accipientis medicamenti qualitate mutatus. Nec poſtea ablui poteſt: ita cortina non dubie confuſura colores, ſi pictos acciperet, digerit ex uno, pingitque dum coquit. Et aduſtæ veſtes firmiores fiunt, quam ſi non urerentur. Plinii, l. xxxv. c. xi.

[r] Στολαὶ αἱ μὲν Ἴσιδος ποικίλαι ταῖς βαφαῖς. Plutarch de Iſide, p. 372.

[s] Ου μὲν τοι ἔς γε τὰ ἱρὰ ἐσφέρεται εἰρίνεα, οὐδὲ συγκαταθάπτεταί σφι· οὐ γὰρ ὅσιον. Herodot. l. ii. LXXXI. de Ægypto.

who tended them[t]. And it was for this reaſon that the family of Joſeph, notwithſtanding his influence in the State, was forbidden to reſide among the inhabitants, and confined to a ſeparate Diſtrict. Theſe opinions ſeem to have been founded on the Prohibition of the Uſe of Animals, a doctrine much inculcated in the Eaſt, and borrowed thence by Pythagoras, who, on his return from Egypt, continued the application of it to Cloathing, as well as to Food[u].

Linen, on the contrary, was there, from the remoteſt Ages, univerſally in uſe. We find that, in the time of Moſes, the Land was employed in the

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[t] "For every Shepherd is an abomination unto the Egyptians."
Gen. c. xlvi. v. 34.

[u] Etiamne cuiquam mirum videri poteſt, ea *lineo* texto involvere, quod puriſſimum eſt rebus divinis velamentum? quippe *lana*, ſegniſſimi corporis excrementum, pecori detracta, jam inde Orphei & Pythagoræ ſcitis, *profanus veſtitus* eſt. Sed enim mundiſſima *lini* ſeges, inter optimas fruges terra exorta, non modo indutui & amictui ſanctiſſimis Ægyptiorum ſacerdotibus, ſed opertui quoque rebus ſacris inde uſurpatur. Apuleii, Apologia, Edit. Caſaub. p. 69.

Λίνον δὲ σπείρεται μὲν ὡς ἔτυχε, ἀλλ' ὅμως ἐπειδὴ μὴ ἀπ' ἐμψύχου ἐδρέφθη, καθαρὸν μὲν Ἰνδοῖς δοκεῖ, καθαρὸν δὲ Αἰγυπτίοις.
Philoſtrat. l. viii. c. vii. ſec. v.

See above, p. 21, line 5 of the text.

Cultivation of Flax[w]. This yielded four ſorts of Linen[x]. It formed the Dreſs of the People[y], who were hence called Grex liniger, and Turba linigera, and particularly of the Prieſts[z], and the Votaries of Iſis[a]. Lucian aſcribes the ſame habit to Anubis[b]. It became an article of Commerce in Egypt; for Jeruſalem[c], Tyre[d], and other places were ſupplied from thence with this merchandize. The Fillets, with which the moſt antient Mummies are bound, reſemble in their texture the coarſe Linen of Ruſſia [e], of which much is yielded by the parts of that Empire, which border on the Country, whoſe Linen, as Herodotus reports, was like that of Egypt.

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[w] Exodus c. ix. v. 31.

[x] Plinii, l. xix. c. i.

[y] Αἰγύπτιοι δὲ εἵματα λίνεα φορέουσι αἰεὶ νεόπλυτα, ἐπιτηδεύοντες τοῦτο μάλιστα.——Herodot. l. ii. XXXVII.
Ἐνδεδύκασι δὲ κιθῶνας λινέους——Ib. LXXXI.

[z] Ἐσθῆτα δὲ φορέουσι οἱ ἱρέες λινέην μούνην.——Herodot. l. ii. XXXVII.

[a] Tunc influunt turbæ ſacris divinis initiatæ, viri ſeminæque omnis dignitatis & omnis ætatis, linteæ veſtis candore puro luminoſi.—Apuleii, Metam. L. XI. de pompa Iſidis.

[b] Σὺ δὲ ὦ Κυνοπρόσωπε, καὶ Σινδόσιν ἐσταλμένε Αἰγύπτιε,
Lucian. Deor. Conc. ſec. iv.

[c] And Solomon had horſes brought out of Egypt, and linen Yarn: and the king's merchants received the linen Yarn at a price.
1 Kings c. x. v. 28.

[d] Say unto Tyrus, O thou that art ſituate at the entry of the ſea, which art a merchant of the people,—Fine Linen—from Egypt was that which thou ſpreadeſt forth.——Ezek. c. xxvii. v. 3—7.

Cotton was likewiſe uſed by them, and the invention of weaving it is attributed to one of their Kings [f]. Pliny deſcribes their Cotton plant, and mentions the particular place where it was produced [g].

I believe it will appear probable, from the following work, that, in the Egyptian proceſs of Dying, the colourleſs matters with which the Cloth was impregnated, previouſly to its immerſion in the Vat, conſiſted of Acid and Alkaline liquors. At leaſt, it is eaſy to imitate the Experiment by their means. And as the clothes, thus ſtained, are ſaid to have been extremely durable, the Acids ſeem to have been of the Vegetable kind, which do not impair the Stuffs, nor diminiſh their durability. For which reaſon, theſe are at preſent uſed in the Eaſt for the fineſt Dyes [h]. Alkaline Salts abounded here, and we are informed that they were applied to the Dyer's uſe [i]. The Nitrum of the Antients was evidently a fixed Alkali, as that word extended to the Vegetable ſalt procured from the Aſhes of Plants by Lixiviation [k], as well as to the Mineral one which Egypt produced, and which is ſufficiently characterized and diſtinguiſhed from the modern Nitre, not only by its readily forming Glaſs, when mixed with Sand, and expoſed to the fire; but by its corroſive quality; by ſeveral of its medicinal effects; and by its remaining unaltered in the fire, even when mixed with Sulphur[l].

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[e] The outward painted covering being removed, nothing but linen fillets were to be ſeen, which encloſed the whole Mummy. The uppermoſt fillets were woven ſomething after the manner of Ruſſia-Sheeting.——Phil. Tranſ. ann. 1764, p. 5.

[f] Clem. Alex. Strom. L. i. p. 225.

[g] Superior pars Ægypti in Arabiam vergens, gignit fruticem, quem aliqui Goſſipion vocant, plures Xylon, & ideo lina inde facta Xylina. Parvulus eſt, ſimilemque barbatæ nucis defert fructum, cujus ex interiore bombyce lanugo netur. Nec ulla ſunt eis in candore mollitiave præferenda. Veſtes inde ſacerdotibus Ægypti gratiſſimæ.——Plinii, l. xix. c. i.

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[h] Savary, D. de Comm. vol. I. p. 1110.

[i] In Nitro optimum quod tenuiſſimum, & ideo ſpuma melior. Ad aliqua tamen ſordidum, tanquam ad *inficiendas* purpuras *tincturaſque omnes.*—Nitrariæ egregiæ *Ægyptiis.*——Plinii, l. xxxi. c. x.

[k] Cremati roboris cinerem nitroſum eſſe manifeſtum eſt.
Plinii, l. xvi. c. viii.

Quercus optima, ut quæ per ſe cinere ſincero vim ſalis reddat: ita infuſo liquore ſalſo, carbo etiam in ſalem vertitur. Quicunque ligno conficitur Sal niger eſt.——Plinii, l. xxxi. c. vii.

Egypt alſo afforded ſeveral other materials likewiſe applicable to the ſame purpoſe. Its Plants and Drugs are celebrated by Homer[m], and are treated of by Pliny[n], Strabo[o], and other Writers; and it furniſhes, even at preſent, many of theſe which are colouring Matters, ſuch as Indigo and Lac[p], beſides various Salts, and other Drugs neceſſary to Dying. Amongſt the minerals produced here, was a ferruginous Earth[q], of which the Utility has been already remarked.

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[l] Plinii, l. xxxi. c. x. et l. xxxvi. c. xxvi.

[m] Ἀιγυπτίη, τῇ πλεῖστα φέρει ζείδωρος ἄρουρα
Φάρμακα.——————

Hom. Odyſ. lib. iv. l. 229.

[n] Plinii, l. xxv. c. ii.

[o] Strabo, l. xvii. p. 809.

[p] Savary, D. de Comm. vol. I. p. 1029.

[q] Ex reliquis rubricæ generibus, fabris utiliſſima Ægyptia.—Picturis autem apta naſcitur in ferrariis metallis. Ex ea fit Ochra.

Plinii, l. xxxv. c. vi.

Painted and printed Clothes, as well as plain Linen and Cotton, are alſo at this day imported from Egypt[r]. And thus it appears that each of thoſe Countries, which formerly carried on this ingenious Art in the earlieſt Ages, have continued in the practice of it down to the preſent time.

Several parts of the Levant alſo excelled antiently in the Tapeſtry or Carpet Manufactures, and executed theſe in the fineſt Colours; employing ſometimes the Needle[s], and ſometimes the Shuttle[t], as we find they continue to do at preſent.

But amongſt the countries of the Eaſt, which practiſed Dying, the Phœnicians were the moſt celebrated; particularly for their Purple Colour. And ſo great was the demand for this article, that Strabo tells us the City of Tyre was grown to a vaſt extent, from the number of workmen employed in its Manufacture [u]. Nor was it only in his time that they attained ſuch great excellence in that Art. They ſeem to have poſſeſt it even from the earlieſt Antiquity; inſomuch that the Origin of the Purple Dye was aſcribed to Melcarthus, the Hercules of that Nation.

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[r] Savary, D. de Comm. vol. I. p. 1029.

[s] Non ego prætulerim Babylonica picta ſuperbe
Texta, Semiramia quæ variantur acu.
Martial. l. viii. ep. 28.

[t] Hæc tibi Memphitis tellus dat munera: victa eſt
Pectine Niliaco jam Babylonis opus.
Martial. l. xiv. ep. 150.

Colores diverſos picturæ intexere Babylon maxime celebravit, & nomen impoſuit. Plurimis vero liciis texere, quæ polymita appellant, Alexandria inſtituit.——Plinii, l. viii. c. 48.

The Books of Moſes make frequent mention of Ornaments compoſed of *Blue*, and *Purple*, and *Scarlet* [w], which Colours are there conſtantly arranged

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[u] Πολὺ γὰρ ἐξήτασται πασῶν ἡ Τυρία καλλίστη πορφύρα· καὶ ἡ θήρα πλησίον, καὶ τ᾽ ἄλλα ἔυπορα τὰ πρὸς βαφὴν ἐπιτήδεια· καὶ δυσδιάγωγον μὲν ποιεῖ τὴν πόλιν ἡ πολυπληθία τῶν βαφείων· πλουσίαν δὲ διὰ τὴν τοιαύτην ἀνδρείαν.
Strabo, l. xvi. p. 757.

[w] "And thou ſhalt make a vail of *blue*, and *purple*, and *ſcarlet*."
Exodus xxvi. 31.

"Aholiab—an embroiderer in *blue*, and in *purple*, and in *ſcarlet*."
Exodus xxxviii. 23.

The ſame Colours, arranged in the ſame Order, occur in the following parts of Exodus xxv. 4.—xxvi. 1, 31, 36—xxvii. 16—xxviii. 6, 8, 15—xxxv. 6, 23, 25, 35—xxxvi. 8, 35, 37— xxxix. 1, 2, 3, 5, 8, 24, 29.—After an interval of ſeveral Centuries from the period deſcribed in this Book, we find that the Colours, employed in the ſame Order: And it appears to me to be worthy of notice, that this Order is the regular *Priſmatic Series* of thoſe Colours; and that each of them may be produced from one and the ſame Ingredient, as I have ſhewn in ſeveral parts of the following Work.

The animal juice, from which the Tyrians procured their Dye, afforded all theſe Colours: Altho' the ſame matter was employed in the production of the different gradations of each[x]. For we are informed that it yielded a Roſe-colour, or pure Red, of a lighter or darker Caſt, according to the Dilution

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the ſacred Ornaments of the Temple, are ſtill mentioned in the ſame *Order*, only a ſlight variation is made in the appellation of the red Colour: "And he " (Solomon) made the vail of *Blue*, and *Purple*, and *Crimſon*," 2 Chron. iii. 14. The word *Scarlet* is generally uſed to ſignify a bright Red: Pliny expreſſes by it a Roſe-Colour, "Coccus, "qui in roſis micat," l. xxi. c. viii. The deeper, or more intenſely coloured Reds are called Crimſon: thus blood is ſaid to be of that Colour, when in a maſs; but when diluted, or ſpread thin on a white ſurface, it is of a bright Red. The intenſer hue of the Tyrian Dye was preferred. See the following note[y], p. 43.

[x] Concharum ad Purpuras, et Conchylia eadem quidem eſt materia, ſed diſtat temperamento.—Plinii, l. ix. c. xxxvi.

tion or Intenſeneſs of the colouring matter[y]; that it alſo gave a Violet or Purple[z], and likewiſe a Blue[a]. Many paſſages relative to this ſubject, beſides thoſe which I have here cited, are diſperſed through the Works of antient Authors. Ferrarius thus recapitulates what Pliny has related concerning it: "Ex "Plinii verbis tria Purpuræ genera ejus interpretes "recte ſtatuerunt, ſingula florum colores provocan"tia. Primum *coccineum, eundemque roſeum Tyria"rum*, ac dibapharum peculiarem, de quo idem "Plinius: Laus ei ſumma color ſanguinis concreti "nigricans aſpectu, idemque refulgens. Secundum "*Amethyſtinum*

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[y] Purpuræ florem illum tingendis expetitum veſtibus in mediis habent faucibus. Liquoris hic eſt minimi in candida vena, unde pretioſus ille bibitur *nigrantis roſæ* colore ſublucens.

Plinii, lib. ix. cap. xxxvi.

Vellus elutriatum mergitur in experimentum. Et donec ſpei ſatisfiat, uritur liquor. *Rubens* color *nigrante* deterior.

Ib. l. ix. c. xxxviii.

[z] Summa medicaminum in libras vellerum, buccini cc, pelagii cxi. Ita fit *Amethyſti* color eximius ille.—Ib.

Alius in malva ad *purpuram* inclinans. Alius in *viola* ſerotina, conchyliorum vegetiſſima.—Lib. xxi. c. viii.

[a] Unde conchyliis pretia, queis virus grave in fuco, color auſterus in *glauco*, & iraſcenti ſimilis mari?—Lib. ix. c. xxxvi.

"*Amethyſtinum violarum æmulum,* coloris nempe "*violacei* ſaturati. Tertium conchyliatum, cujus "colorem in univerſum ait fuiſſe Plinius auſterum "in *glauco,* & iraſcenti ſimilem mari, id eſt *cæruleum*[b]."

The Experiments made by modern Obſervers on the Liquor of the Buccinum and Purpura, ſhew that the ſame Colours are capable of being obtained from it by Chymical means[c].

I am induced to think that the Blue, Purple, and Red Colours, ſo frequently mentioned in the Scripture, were the product of Phœnicia, as well from theſe Circumſtances, as from the Antiquity of the Dying Manufactures eſtabliſhed in that Country; where they ſeem to have flouriſhed long before the foundation of Tyre. Melcarthus, to whom the Diſcovery of the Purple Dye is aſcribed, preceded that Period many ages[d]. Homer, who makes no mention of Tyre[e], on account of the recency of its ſettlement at the time of the Trojan War, ſpeaks nevertheleſs of the *variegated Clothes* of Sidon, as Works of great magnificence, which ſeem to have required much Skill in the art of colouring the materials employed in their fabrick[f]. Sidon was alſo at a later date eſteemed for its Purple[g].

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[b] Ferrarius de Re Veſtiaria, l. ii. c. vii.

[c] Mem. de l'Acad. R. des Sciences, de Paris, ann. 1711, par M. de Reaumur.——Ib. ann. 1736. par M. du Hamel.

[d] Cumberland, Orig. Gent. London, 1724, p. 114.——Phœn. Hiſt. p. 160.

On this ſubject, a remarkable agreement is found between the ſacred and profane Accounts of the earlieſt Times. For Joſeph, in the neighbouring Land of Canaan[h], wore a *Coat of many Colours,*

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[e] Οἱ μὲν οὖν ποιηταὶ, τὴν Σιδόνα τεθρυλλήκασι μᾶλλον. Ὅμηρος δὲ οὐδὲ μέμνηται τῆς Τύρου.——Strabo, l. xvi. p. 756.

[f] Ἔνθ᾽ ἔσαν οἱ πέπλοι παμποίκιλοι, ἔργα γυναικῶν
Σιδονίων, τὰς αὐτὸς Ἀλέξανδρος θεοειδὴς
Ἤγαγε Σιδονίηθεν.——— Iliad. l. vi. lin. 289.

[g] Lanæ Amethyſtinæ.
Ebria *Sidoniæ* cum ſim de ſanguine conchæ,
Non video quare ſobria lana vocer.
Martial, l. xiv. ep. cliv.

[h] The Canaanites and Phœnicians were originally the ſame people. Cumberland, and other learned Writers of ſacred Antiquity, conſtantly uſe theſe names as ſynonimous: and Herodotus includes, under the common appellation of Palœſtine, Phœnicia with the reſt of Syria, and the whole country as far as to Egypt.—Herodot. l. vii. c. lxxxix.

lours[i]. And, at the ſame period, ſtuffs dyed Red appear to have been there in common Uſe[k].

Egypt was, in the remoteſt ages, frequented by the Ships of Phœnicia. Herodotus[l] relates that the inhabitants of that Country, *immediately* after their ſettlement in it, ſent their Fleets to traffic with the Egyptians; and Strabo mentions their Works of Purple, as equal in Antiquity to their exerciſe of Navigation[m], of which art they were the Inventors[n]. In the Odyſſey, the Commerce between

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c. lxxxix.—ὗτοι δὲ οἱ Φοίνικες τοπαλαιὸν ὄικεον (ὡς αὐτοὶ λέγȣσι) ἐπὶ τῇ Ἐρυθρῇ θαλάσσῃ· ἐνθεῦτεν δὲ ὑπερβάντες τῆς Συρίης οἰκέȣσι τὸ παρὰ θάλασσαν· τῆς δὲ Συρίης τȣ̃το τὸ χωρίον ϗ τὸ μέχρι Αἰγύπτȣ πᾶν, Παλαιςίνη καλέεται.

[i] Geneſis, c. xxxvii. v. 23.

[k] Ib. c. xxxviii. v. 28.

[l] Φοίνικας—οἰκήσαντας τȣ̃τον τὸν χῶρον τὸν ϗ νῦν οἰκέȣσι, ΑΥΤΙΚΑ ναυτιλίῃσι μακρῇσι ἐπιθέσθαι. ἀπαγινέοντας δὲ φορτία Αἰγύπτιά τε καὶ Ἀσσύρια.
Herodot. l. i. I.

[m] Τῇ τε ναυτιλίᾳ, καθ' ἣν ἁπάντων τῶν Ἀεὶ κρείττȣς εἰσὶ κοινῇ Φοίνικες, καὶ τοῖς Πορφυρίοις.—Strabo, l. xvi. p. 757.

[n] Οἳ πρῶτοι νήεσσιν ἐπειρήσαντο θαλάσσης,
Πρῶτοι δ' ἐμπορίης ἁλιδινέος ἐμνήσαντο.
Dionyſ. Perieg. lin. 908.

between theſe Nations is alſo noticed[o]: and it ſubſiſted after Tyre had attained to its height, from whence its principal Port was called the Egyptian Haven[p].

Phœnicia, which ſignifies a Red Colour, appears to me to have taken its name from the Dye, for which it was ſo renowned. Many antient Writers derive that Appellation from the Colour of the Red Sea, from whoſe Coaſts this people are ſaid to have migrated[q]: but the moſt judicious of them juſtly explode that Etymology[r], without, however, ſubſtituting any other in its place. I therefore think that, agreeably to the frequent cuſtom of nations, this country was diſtinguiſhed by the name of its original, and moſt antient, Produce and Manufacture.

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[o] Odyſſ. l. xiv. lin. 288.

[p] Τύρος—δύο δ' ἔχει λιμένας, τὸν μὲν κλειστόν, τὸν δ' ἀνειμένον, ὃν Αἰγύπτιον καλοῦσιν.—Strabo. l. xvi. p. 757.

[q] Οἱ δ' ἁλὸς ἐγγὺς ἰόντες, ἐπωνυμίην Φοίνικες,
Τῶν δ' ἀνδρῶν γενεῆς οἱ Ἐρυθραῖοι γεγάασιν.
Dionyſ. Perieg. lin. 906.

See alſo the preceding Note [h], p. 45.

[r] Ὁμόιοι δ' εἰσὶ τούτοις, ϗ οἱ Σιδονίους ἐν τῇ κατὰ Πέρσας θαλάττῃ διηγούμενοι, ἢ ἄλλοθί που τοῦ Ὠκεανοῦ, ϗ τοὺς Φοίνικας δὲ ὁμοίως. Τῆς δ' ἀπιστίας αἴτιον οὐκ ἐλάχιστόν ἐστι, τὸ ἐναντιοῦσθαι ἀλλήλοις τοὺς λέγοντας. Οἱ μὲν γὰρ ϗ τοὺς Φοίνικας, ϗ τοὺς Σιδονίους τοὺς καθ' ἡμᾶς ἀποίκους εἶναι τῶν ἐν τῷ Ὠκεανῷ φασι, προστιθέντες ϗ διὰ τί Φοίνικες ἐκαλοῦντο, ὅτι ϗ ἡ θάλαττα Ἐρυθρά.
Strabo, l. i. p. 42.

As it appears probable from theſe conſiderations, that the Jews obtained theſe Colours while they ſojourned in Egypt, ſo I attribute the peculiar Frequency with which they are mentioned in Exodus, to their having poſſeſſed themſelves of them before they departed from thence, in the manner detailed in that Book. We afterwards find that Solomon procured thoſe Dyes immediately from Tyre, by permiſſion of Huram, who reigned there[*].

The regular Arrangement of theſe Colours in their *Priſmatic Order*, ſo conſtantly obſerved, not only in the numerous recitals of them in the earlier parts of the Scripture, but in the Accounts which relate to the uſe of them, after an interval of many Ages, cannot, I believe, have been made accidentally, or without deſign: but muſt have ariſen from an accurate Knowledge of the Subject.

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[*] 2 Chron. c. ii. v. 7, 14.

And I am the more confirmed in this opinion, by the Teſtimony of thoſe antient Authors, who aſſure us that the Phœnicians, who ſupplied theſe Colours, were not more renowned for the production of their Dye, than for the Skill of their Philoſophers, amongſt whom Moſchus, before the time of the Trojan War, cultivated the Doctrine of Atoms [t] already treated of; the Connection of which, with the Differences and Gradations of Colours, appears throughout the following Work.

This Country poſſeſſed many natural advantages for qualifying it to arrive at a very high degree of excellence in the Art of Dying. Its Coaſts afforded the Shell-fiſh, from which their principal Dyes were obtained. And as its numerous Fleets, and extenſive Commerce, opened to it a communication with the moſt diſtant Nations of the World, it was enabled to procure from thence whatever was neceſſary to its Manufactures.

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[t] Ἀϛρονομίαν δὲ ϗ ἀριθμητικὴν παρὰ Φοινίκων· νυνὶ δὲ πάσης ϗ τῆς ἄλλης φιλοσοφίας εὐπορίαν πολὺ πλείϛην λαβεῖν ἐϛιν ἐκ τούτων τῶν πόλεων. Εἰ δὲ δεῖ Ποσειδωνίῳ πιϛεῦσαι, καὶ τὸ περὶ τῶν ἀτόμων δόγμα, παλαιόν ἐϛιν ἀνδρὸς Σιδωνίου Μόσχου πρὸ τῶν Τρωϊκῶν χρόνων γεγονότος.

Strabo, l. xvi. p. 757.

It is well known that the Phœnicians reſorted to Britain, at a very early period of Hiſtory: and I think it very probable that the *Tin*, which they brought from this Iſland, was uſed by them in *Dying*; as we find this Metal is neceſſary to the production of *Red* Colours, whether from animal or vegetable materials.

We learn from the teſtimony of Pliny, who gives us the proportion of the Ingredients, and many other particulars relative to the Tyrian Dye, that the Vat in which it was boiled, was made of Tin[a]: "Fervere in Plumbo." And it is manifeſt, from many paſſages in his writings, that by Plumbum he here means Tin. For, according to him, Plumbum was divided into White and Black; the former of which was the moſt valuable, and to that he attributes the Names and Qualities of Tin; although he generally, on account of its excellence, calls it Plumbum, omitting the Epithet Candidum.

Thus he informs us that the Inſulæ *Caſſiterides* received their name from this Metal[w]; that it was known before the time of Homer, and was called by him, and by the Greeks in general, *Caſſiteron*[x]; that it was the Metal uſed in ſoldering Lead[y], for which purpoſe Tin is ſtill employed by the Plumbers. The operation of Tinning, by its means, is alſo deſcribed[z]. The Plumbum nigrum is repreſented by him as common Lead, out of which Pipes and Sheets were formed[a].

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[a] Fervere in Plumbo, ſingulisque aquæ amphoris centenas atque quinquagenas medicaminis libras æquari, ac modico vapore torreri, & ideo longinquæ fornacis cuniculo.—Plinii, l. ix. c. xxxviii.

That in theſe Arts the Eaſtern Nations had attained to a great Superiority at a very early period, appears from a comparative view of their ſtate in

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[w] Sunt Inſulæ *Caſſiterides* dictæ a Græcis a fertilitate Plumbi.
Plinii, l. iv. c. xxii.
Plumbum ex *Caſſiteride* Inſula primus apportavit Mediacritus.
Ib. l. vii. c. lvi.

[x] *Plumbum*-album habuit autoritatem & Iliacis temporibus, teſte Homero, *Caſſiteron* ab eo dictum.——Ib. l. xxxiv. c. xvi.
Plumbum pretioſiſſimum candidum a Græcis appellatum *Caſſiterum*.
Ib.

[y] Jungi inter ſe plumbum nigrum ſine *albo* non poteſt.—Ib.

[z] *Plumbum album* incoquitur æreis operibus, Galliarum invento, ita ut vix diſcerni queat ab argento, eaque incoctilia vocant.
Ib. c. xvii.

[a] Nigro plumbo ad fiſtulas laminaſque utuntur.—Ib. c. xvii.

Greece much later; for Herodotus profeſſes that he is intirely ignorant of the Inſulæ Caſſiterides [b], when they had long afforded materials for extenſive Commerce and curious Arts to the Phœnicians.

The Uſe of the Tyrian Dye ſubſiſted, till the unreaſonable Jealouſy of the Eaſtern Emperors put an end to this, with almoſt all other productions of Art. For weakly judging that their Dignity depended on the Colour of their Cloaths, or the materials of which they were made, they prohibited the Uſe of every thing that was worn by themſelves. We have, in the Juſtinian Code, the Laws by which Gold, Jewels, Silk, and other Ornaments, are forbidden to be wrought, except within the walls of the Palace. And this Order was ſo rigorouſly enforced, that it was made a capital Offence even to preſent the Emperor with ſuch gifts [c]. The Manufactures of Purple, which till that time had ſo greatly flouriſhed, did not eſcape the bad effects of this Monopoly. The Laws are extant by which private perſons are forbidden the Uſe of that Dye,

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[b] Ὄυτε νήσους οἶδα Κασσιτερίδας ἐούσας, ἐκ τῶν ὁ κασσίτερος ἡμῖν φοιτᾷ. Herodot. l. iii. CXV.

[c] Cod. l. xi. tit. viii. xi.

Dye[d], or any other reſembling it[e], under the penalty of treaſon : and the Fairs where it had uſually been ſold were ſuppreſſed[f].

Such impolitic regulations occaſioned a quick decay of theſe Works in the Eaſtern Empire. This inconvenience, as far as it related to their perſonal uſe, the Emperors at length ſaw, and endeavoured to remedy, by obliging the Deſcendents of the Tyrian Dyers, as well as other Artiſts, to practiſe the Trades of their Anceſtors[s]: a Policy which did not, however, prevent the total Loſs of this, and all other Arts, in thoſe parts of the empire, where theſe Prohibitions prevailed.

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[d] Quæ tincta conchylio, quæ nullius alterius permixtione contexta ſunt: proferantur ex ædibus, tradanturque tunicæ aut pallia ex omni parte texturæ cruore infecta conchylii. Nulla ſtamina ſubtexantur tincta conchylio, nec ejuſdem infectionis arguto pectine ſolidanda fila decurrant: reddenda ærario olobera veſtimenta virilia protenus offerantur. Nec eſt ut quiſquam de abjurato pretio conqueratur: quia ſufficit calcatæ legis impunitas. Ne quis vero nunc hujuſmodi ſuppreſſione in laqueos novæ conſtitutionis incurrat: alioqui ad ſimilitudinem læſæ majeſtatis periculum ſuſtinebit.
Cod. l. xi. tit. viii.

[e] Vellera adulterino colore fucata, in ſpeciem ſacri muricis intingere non ſinimus. Ib.

[f] Purpuræ nundinas, licet innumeris ſint conſtitutionibus prohibitæ, recenti quoque interminatione vetamus: & ideo ſeptimum de ſcrinio exceptorum—ad baphias Phœnices per certum tempus mitti præcipimus, ut omnis fraus eorum prohibeatur ſolertia, timentium ne quæſitis longo ſudore ſtipendiis careant. Ib.

The Colouring and Preparation of Leather, in which ſeveral Parts of the Levant ſtill excel, were practiſed in the Eaſt ſo early, that *Skins dyed red* are frequently mentioned in the Books of Moſes, amongſt the ſacred Ornaments: and other inſtances of the antient exerciſe of ſuch Works frequently occur.

I have thus endeavoured to trace theſe Manufactures, from the remoteſt Antiquity. To ſome Readers the Conſideration of them may appear of little Conſequence or Utility: but if we view them as Objects of Commerce, and reflect on the relation they bear to Sciences which give great Superiority to the Countries where they are found out or cultivated, we ſhall ceaſe to look on them with diſregard, and ſhall rather imitate the Wiſdom of antient nations in the Reſpect which they paid to the Authors or Improvers of them. It was thus from a ſenſe of the great national Utility of their Purple Dye, that the Phœnicians attributed its invention, which was the principal Foundation of their Trade and Wealth, to the chiefeſt of their Gods.

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[s] Cod. l. xi. tit. vii.

Amongſt the ſeveral Arts, which owed their Origin to the Knowledge and Ingenuity of this People, that of making Glaſs was one of the moſt conſiderable: and the execution of it required no leſs chymical Skill, than that which has been laſt examined; eſpecially when colouring matters were added to the tranſparent Maſs. As that Country originally exerciſed theſe Works, and furniſhed the Sand which they required[h], Sidon formerly excelled in them[i].

They were likewiſe carried on in other Parts of the Eaſt. In India glaſs was antiently made of Cryſtal[k]. The Egyptians alſo had ſuch Manufactures, at a very early date. Strabo, who viſited Alexandria, was told by the Workmen there that their Country afforded an Ingredient, without which the beſt Glaſs, and particularly that which is *coloured*, could not be made[l]. I do not doubt that this neceſſary material was the mineral Alcali, which, as has been already remarked, was found there in great abundance[m].

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[h] Plinii, l. xxxvi. c. xxvi.

[i] Ib.——Μεταξὺ δὲ τῆς Ἄκης ϗ Τύρου, θινώδης αἰγιαλός ἐστιν ὁ φέρων τὴν ὑαλῖτιν ἄμμον· ἐνταῦθα μὲν οὖν φασὶ μὴ χεῖσθαι· κομισθεῖσαν δὲ εἰς Σιδόνα τὴν χωνείαν δέχεσθαι· τινὲς δὲ ϗ τοῖς Σιδονίοις εἶναι τὴν ὑαλῖτιν ψάμμον ἐπιτηδείαν εἰς χύσιν. Strabo, l. xvi. p. 758.

[k] Plinii, l. xxxvi. c. xxvi.

The Teſtimony of Hiſtorians on this ſubject is confirmed by ſeveral antient Egyptian Reliques ſtill extant. Among theſe I have ſeen variouſly coloured Glaſſes, ſome of which are in my own poſſeſſion. And there is, in the Britiſh Muſeum, a Mummy of great Antiquity which is covered with ſuch Beads.

Several ſmall Figures frequently found depoſited with the Mummies, which they reſemble in Shape, are covered with a *blue Glazing*, ſimilar to that of the Chineſe Porcelain. I have examined ſome of this blue Covering taken from two of theſe Egyptian Figures, by mixing it with ſeveral vitreous ſubſtances, and expoſing it to a conſiderable heat in cloſe crucibles: from which trials it did not ſeem to differ from *Cobalt*.

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[l] Ἤκουσα δ' ἐν τῇ Ἀλεξανδρείᾳ παρὰ τῶν ὑαλουργῶν, εἶναί τινα ϗ κατ' Αἴγυπτον ὑαλίτιν γῆν, ἧς χωρὶς οὐχ οἷόν τε τὰς πολυχρόους ϗ πολυτελεῖς κατασκευὰς ἀποτελεσθῆναι. Strabo, l. xvi. p. 758.

[m] See p. 38 above.

There is a paſſage in Theophraſtus, which appears to me to relate to this Subject. That Author having mentioned the *Cyanus*, a *blue* mineral Subſtance, capable of preſerving its Colour in the Fire, adds, that the Egyptians uſed a *factitious Sort* invented by one of their Kings[n]. Naturaliſts agree that the Cyanus is the Lapis Lazuli of the Moderns[o]. And this opinion is confirmed by the account given of it by Pliny, who informs us that it was of an *azure* colour, (colore cœruleo[p]) and that it was ſometimes variegated with Gold Duſt[q].

Ultramarine conſiſts of this Stone pulverized, either with or without the Aſſiſtance of the Fire, as

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[n] Καὶ Κυανὸς, ὁ μὲν αὐτοφυής· ὁ δὲ σκευαστὸς, ὥσπερ ἐν Αἰγύπτῳ.—— Σκευαστὸς δ' ὁ Αἰγύπτιος. καὶ οἱ γράφοντες τὰ περὶ τοὺς βασιλεῖς, καὶ τοῦτο γράφουσι, τίς πρῶτος βασιλεὺς ἐποίησε τεχνητὸν Κυανὸν, μιμησάμενος τὸν αὐτοφυῆ. Theophraſt. de Lapid. XCVIII.

[o] Lapis Lazuli, Cyanus Græcorum, Stellatus Meſues, eſt lapis petroſus, mollior, cœruleus, ut plurimum pyritæ punctis notatus.
Baumer Hiſt. nat. Lapid. § clxv.

[p] Plinii, l. xxxvii. c. ix.

[q] Ineſt aliquando & aureus pulvis. Ib.

the Pigment prepared from the blue Mineral is deſcribed by Theophraſtus[r]. This is uſed as a Colour in Enamel, as well as in other methods of Painting. But the preparations of Cobalt exceed, in uſe and beauty, thoſe of Lapis Lazuli, in Works which undergo a conſiderable degree of Fire.

I think it very probable, from hence, that the factitious Blue, diſcovered by the Egyptian King, and afterwards uſed inſtead of the Original, was a Glaſs or Enamel tinged with Cobalt, ſuch as is now employed in Europe and China[s]. Pliny, who generally adds to his Quotations from Theophraſtus ſome circumſtances which illuſtrate them, gives this deſcription of the Invention: "Cyanus adulteratur "maxime tinctura, idque in gloria regis Ægyptii "aſcribitur, qui primus eam tinxit." Lib. xxxvii. c. ix. As this inſtructive Author uſes the word *Tinctura*, to ſignify the Compoſition by which the Cyanus was adulterated, I was perſuaded that the application,

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[r] Φόρον Κυανοῦ, τοῦ μὲν ἀπύρου, τοῦ δὲ πεπυρωμένου.
Theophraſt. de Lapid. XCIX.

[s] Du Halde informs us that Lapis Lazuli abounds in that Country: perhaps it was there applied to the Painting of Porcelain, before the introduction of Cobalt.

application of this Expreſſion, if found in other parts of his Work, would point out the particular matter to which it alludes. Accordingly it appears from the paſſage here cited[t], that it means *Glaſs* tinged with Blue, or other Colours: ſuch as the Blue Enamel or Glazing of Porcelain and other earthen ware, which conſiſts of Glaſs coloured with Cobalt. I therefore think myſelf authorized, from theſe conſiderations, to tranſlate the Sentence thus: "The Cyanus is chiefly adulterated by a tinged "*Glaſs*, and the merit of the Invention is aſcribed "to an Egyptian King, who firſt tinged that ſub- "ſtance." It is probable that Democritus, on his return from hence, brought into Europe the Method of making coloured Glaſſes, and thereby counterfeiting Gems: as we are told that they were invented by him[u], but certainly might more properly be ſaid to have been introduced by him.

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[t] De origine Vitri, & ratione faciendi, & de obſidiano Vitro.— Fit & in *Tinctura* genere obſidianum, ad eſcaria vaſa totum rubens, *Vitrum*, atque non tranſlucens, hæmatinon appellatum. Fit & album & murrhinum, aut hyacinthos *ſapphiroſque* imitatum, & omnibus aliis coloribus. Nec eſt alia nunc materia ſequacior, aut etiam *picturæ* accommodatior. Plinii, l. xxxvi. c. xxvi.

[u] Excidit porro vobis eundem Democritum inveniſſe, quemadmodum Ebur poliretur, quemadmodum decoctus calculus in ſmaragdum

The Chymical Skill of this Nation appears alſo in ſeveral other inſtances, and particularly in the application of Aromatics, Reſins, Salts, and other materials, to the Preſervation of Animal and Vegetable ſubſtances. I ſhall, however, only obſerve on this head that, after an interval of ſo many Ages, not only the Painting with which theſe Antiquities were adorned continues ſtill unimpaired, but Plants, remaining perfect and entire, are ſometimes found enveloped in them.

During the examination of a Mummy, which was inſpected by ſome learned Members of the Royal Society[*], I had an opportunity of obſerving that a bulbous Root, together with its outer membrane,

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dum converteretur, qua hodieque coctura inventi lapides coctiles colorantur.—Senecæ, Epiſt. xc.

I have not ſcrupled to give to the words *lapides coctiles* this conſtruction. For experience ſhews that Flints, Pebbles, or other Stones cannot, by being boiled in any Liquor, be made to imitate coloured Gems. But ſuch vitreous Stones, by being expoſed to a ſufficient heat, with a proper Flux, are capable of being melted and boiled: by which means they become *Glaſs*, and by the addition of colouring-matter counterfeit Gems. The word *coctilis* is often literally uſed in this ſenſe, to ſignify earthy or vitreous ſubſtances expoſed *per ſe* to a great heat: thus Brick walls are called muri *coctiles*.

[*] Philoſ. Tranſ. ann. 1764.

brane, incloſed by the fillets which bound one of the feet, retained its natural Colour and gloſſy appearance. Nor could it have been diſtinguiſhed, by the ſight, from ſuch a Root freſhly taken from the ground in a State of Vegetation. And this is not the only Account, of the Colour and Freſhneſs of Plants thus preſerved, for Proſper Alpinus gives a ſimilar inſtance[x], which is quoted in the Paper here referred to.

I have thus traced ſuch of the antient Arts and Manufactures as dealt in the Management and Uſe of colouring Subſtances: in each of which much chymical and philoſophical Skill ſeems to have been exerted. And in the purſuit of this Inquiry, the Subject appeared to me to be ſtill more worthy of notice from the frequent inſtances, which it affords, of the Permanency of theſe uſeful Works from the remoteſt Ages to the preſent time, in the Countries where they were originally eſtabliſhed.

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[x] Incredibile dictu, rami roriſmarini qui una cum idolo inventi fuerunt, folia uſque adeo viridia & recentia viſa fuerunt, ut eâ die a plantâ decerpti & poſiti apparuerint.

Proſper Alpinus Rer. Ægypt. 1735, p. 36.

I ſhall proceed to obſerve, that the Oriental Nations continue the practice of many of theſe, ſome of which we have borrowed from them, while others ſtill remain unknown to us: And that Chymiſtry in general was derived to us from them.

Upon our diſcovery of China, the moſt Eaſtern part of Aſia, we found that Nation poſſeſſed of Gunpowder: a Compoſition which could not have been made without a conſiderable Knowledge of that Science. Dying alſo, and methods of preparing Colours, have been conſtantly exerciſed there, as well as in India; and theſe in ſo perfect a manner, that we have not hitherto been able to equal them. Many Salts, which are the principal Ingredients in various proceſſes, were originally Productions of the Eaſt, and continue to be imported from thence: as Nitre from India, and Sal Ammoniac from Egypt; the Europeans not having, even at preſent, attained a ſufficient facility in their formation, to ſupply the quantity required for their own Uſe.

Several other chymical Operations, in which we are unpractiſed, are carried on by the Aſiatics: among theſe are the Preparation of inflammable Spirits from Milk; the various Combinations of

Metallic matters for uſe and ornament, in which they peculiarly excell; and to theſe may be added the Manufactures of Porcelain; the Compoſition and Application of Varniſhes; and many others which are as yet imperfectly imitated by us.

Nor was the ſuperior Skill of this Part of the World confined merely to the *Practice* of ſuch Works; for, at the time when Arts and Learning were loſt in Europe, we find that they flouriſhed in the Eaſt. It was at that Period, that the firſt *extant* Books of Chymiſtry were written by Geber, in the Arabic Language: and this Oriental Author treats his ſubject, in a manner which ſhews that it was not recent or unfamiliar in his Age and Country. Boerhaave, ſpeaking of his Works, ſays, that "they " contain abundance of curious and uſeful things " about the nature of Metals, their purification, fu- " ſion, malleability, &c. with excellent accounts " of Salts, and Aquæ Fortes. Several of his Ex- " periments are verified by preſent practice, and " have paſſed for modern Diſcoveries: the exactneſs " of his Operations is really ſurprizing, except per- " haps in what relates to the Philoſopher's Stone."

After Geber, who lived in the ſeventh Century, Chymiſtry continued long confined to the Eaſtern Nations, among whoſe Authors in the eleventh, Rhaſes, Avicenna, and others, who united the ſtudy of Medicine and of this Art, preceded any Writers, on that Subject, in Europe.

The Countries in which Learning chiefly flouriſhed, in that age, are enumerated in the following paſſage, which I find in Voſſius de Philoſophia, l. xiv. quoted from Leo Oſtienſis: "Conſtantinus "Afer, relictâ Carthagine, ubi ortus fuerat *Babylo-* "*niam* petiit: ubi diſciplinis omnibus *Chaldæorum*, "*Arabum*, *Perſarum*, *Ægyptiorum*, & *Indorum* pleniſſi-"mè inſtructus, poſt annos xxxix ad Africam rediit."

And it is remarkable that theſe Seats of Literature and Philoſophy were the ſame from which Democritus, and other Sages, had, at a very early Period, derived their Doctrines.

I have thus endeavoured to inveſtigate theſe Doctrines, and have ſhewn that ſome of them were conſentaneous to thoſe which Sir Iſaac Newton entertained, relative to the Permanency of the component Particles of Bodies.

It is not improbable, however, that theſe Opinions might have originally occurred to that great Philoſopher, from the Conſideration, not only of thoſe natural Appearances which he mentions in the paſſage above cited, but alſo more particularly from ſome of his own Experiments.

Light conſiſts of perhaps the ſmalleſt Particles of Matter which can fall under our inſpection: yet theſe, after having been variouſly united or ſeparated by ſeveral Refractions or Reflexions, are conſtantly found to have ſuffered no Alteration.

If I may be permitted to add to this, the Conſideration of ſome circumſtances which I have related in the following Work, I ſhall remark that this Indeſtructibility appears alſo from the Experiments, by which all the primary Colours are there ſhewn to have been produced from one and the ſame Subſtance. For, as the Changes of theſe Colours, are capable of being often repeated, without impairing their Luſtre, it is evident that the *component Particles* are not, by theſe means, broken or deſtroyed, but only united into larger, or ſeparated into ſmaller, Maſſes.

From the Obſervation of this Cauſe of the Changes of Colours in permanently-coloured Bodies, I have been able to apply the Principle, which reſulted from it, to the Improvement of ſeveral Arts: particularly to thoſe of Dying, Painting, and ſuch others as depend on the Management or Knowledge of coloured materials.

From thence I have frequently had an opportunity of pointing out to Dyers, the Cauſe and Remedy of certain Defects which have happened in their Works: as this Theory is eaſily applicable to their Art. Thus, when *Red* Clothes have inclined too much towards a *Yellow* hue, I have taught the workmen employed in dying them, that their colouring Matter was too much *attenuated* or *diſſolved*; and that, when ſuch Clothes inclined too much towards *Purple*, on the contrary a ſufficient Solution or Attenuation had not taken Place. And the ſame Rule equally obtains in Dyes of all other Colours, as I have often experienced.

The Experiments which are mentioned in this Inquiry, and the Principle deduced from them, may alſo tend to improve the Art of Painting, as many of the Materials employed in it are ſubject to alterations, which I have explained, and which may in a great meaſure be prevented by an Attention to thoſe parts of Chymiſtry and Optics, which are there treated of. Theſe Defects ariſe from ſeveral Cauſes, which ſhould be ſeparately conſidered and guarded againſt, as,

1. From the aptneſs of the Paints themſelves to part with or to receive ſome matter, by which they become decompoſed, and, in conſequence of their Decompoſition, undergo a Change of Colour. Thus all the *white* Pigments prepared from metallic ſubſtances are, by the acceſſion of Phlogiſton, readily changed to *black*, which in the Order of Colours is contiguous to *white*. And this aptneſs to become black is proportioned to the Whiteneſs of the metallic ſubſtances: for their Whiteneſs ariſes from their Solution, by which their Phlogiſton is loſt; and it is a Rule in Chymiſtry, that thoſe Metals attract Phlogiſton with the greateſt force, which have undergone the moſt ſubtile Diviſion.

It is on this account that the Magiſtery of Biſmuth, which is the whiteſt of metallic Preparations, is quickly turned black by a mere expoſure to the

Air, for from hence it readily regains inflammable matter. And it is by the ſame means that the colourleſs Solution of Lead, uſed as a ſympathetic Ink, is affected in the ſame manner by phlogiſtic Vapours, and that White Lead reſumes its metallic Colour and Luſtre, when expoſed to ſuch Effluvia. The Oils alſo uſed in Painting readily communicate inflammable matter to ſuch ſubſtances.

2. All the Pigments, into whoſe Compoſition Acid, Alcaline, or Calcareous matters enter, are ſubject to be decompoſed, and ſuffer Changes of Colour; either by the Eſcape of thoſe Principles, or by their Mixture with other Ingredients of an oppoſite quality. And amongſt theſe muſt be reckoned, not only the Paints themſelves, but the Oils, Varniſhes, and ſeveral other Subſtances.

3. The Colours of Pigments are affected by the Preſence of Air, or even by its Abſence, in a manner which merits the inquiry of Painters. Thus white Paints, to which the Air has not acceſs, are well known to turn Yellow; and many of the other Colours, from the ſame Cauſe, are equally impaired, although the alterations thus produced in them are not ſo commonly noticed. A very remarkable

effect of the Air, in changing a primary Colour into another next in Order to the former, offers itſelf in the Uſe of Indigo, a ſubſtance formerly much employed in Painting, to which Pruſſian Blue has lately been ſubſtituted, although it is a much leſs durable Paint[r].

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[r] Painters have been encouraged to rely too much on the durability of Pruſſian Blue, from the aſſurances of all who have hitherto publiſhed Accounts of that pigment; in which they aſſert that it is not capable of being acted upon by any of the Acids. I have found by ſeveral Experiments, which I have made upon it, that their Opinion is extremely erroneous, and calculated to lead the Artiſts who rely on it into a falſe confidence in the uſe of it: which cannot fail, in time, of conſiderably impairing their Works. I have conſtantly experienced that Pruſſian Blue is readily acted on by Oil of Vitriol, by which it immediately loſes its *blue* Colour, and is changed into a light *brown* or *grey:* and it is ſo far diſſolved by the Acid, as to be miſcible with Water and other Liquors; but upon ſuch Mixture, or by the addition of an Alcali, the Oil of Vitriol is diſengaged, and the Pruſſian Blue reſumes its Colour. It ſhould here be obſerved, that not only many ſubſtances are uſed in Painting, into whoſe compoſition the vitriolic Acid enters; but alſo the ferruginous Earths, which conſtitute the greateſt part of the Materia Pictoria, generally contain ſome of that Acid, which cannot fail to act on the Pruſſian Blue, ſo as to impair or deſtroy its Colour, when they are mixed with it. And the inconvenience attending the Uſe of this Paint is the greater, becauſe the Change of its Colour does not uſually take place till a conſiderable time after the Picture is finiſhed. For it appears from the Experiment which I have here related,

When Indigo is diſſolved in an Alcali, the Solution is *green*; but when a thin Surface of this Solution is expoſed to the Air, it almoſt inſtantly becomes *blue*. And this Change of Green to Blue, from the Attenuation of the colouring matter by the entrance of Air into it, ſeems to ariſe from the great Affinity which the Air has to Alcaline Salts, and the readineſs with which it is regained by them, in proportion as they have been deprived of it by any proceſs.

I have mentioned theſe few particular inſtances of the neceſſity of underſtanding and guarding againſt ſuch Changes; but thoſe which may be produced are almoſt as numerous as the Paints which are employed; and are increaſed to a ſtill greater Variety, by their ſeveral Mixtures with each other, as well as with the Oils, Varniſhes, and other materials.

I have, with ſome care, attended to the Circumſtances relative to this Art, and have made a conſiderable

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related, that while the Oil of Vitriol is mixed with Water, it does not act upon the Pruſſian Blue; but in proportion as the Painting dries, the Acid acquires its former force to deſtroy the *Blue* and render it *brown*.

derable Number of Experiments on the Subject: But I do not think them proper to be ſubmitted to the Public at preſent, as many further proceſſes of Chymiſtry are requiſite to the examination of the ſeveral ſubſtances, hitherto very imperfectly underſtood.

In the mean time, Artiſts may, from the conſideration of what is offered in this Work, be enabled to prevent ſome Changes of Colour to which their materials are ſubject, and to produce new Paints by altering the Colours of the old ones, previous to their Application. The general Principles may alſo ſerve to lead to ſuch particular Experiments as are neceſſary for their right Management and Knowledge of them.

It is certain that, until they are able to underſtand the Nature and Qualities of the various materials which are uſed by them, ſo as to be acquainted with the alterations they are liable to, either when ſeparate or combined, they will conſtantly labour under the neceſſity of making new Trials, which muſt greatly retard the progreſs of their Art. And it is much to be regretted that ſome Painters, whoſe

Works would otherwiſe have great merit, have the misfortune to ſee their Colouring undergo Changes, which intirely deſtroy the Effect they had originally produced.

From certain Inſtances which have occurred in this Inquiry, it appears that the medicinal Qualities of ſeveral ſubſtances may frequently be diſtinguiſhed by their Colours.

If, according to the opinion generally entertained by Phyſicians, metallic bodies acquire active Powers in proportion as they are more minutely *divided:* ſuch Qualities may, in a great meaſure, be judged of by the *Colours* of the Preparations: becauſe thoſe Colours correſpond with their ſeveral degrees of *Solution* or *Diviſion.*

In this Inquiry, I have amply conſidered and compared the various degrees of Solution of Iron, as well as thoſe of Mercury; and it will appear from thence that, in every Preparation of thoſe Metals, an exact correſpondence is found between their Colours and their degrees of Attenuation.

The Experiments and Obſervations which are to be found in p. 39, ſhew that the Nature and Proportion of the Ingredients, which enter into the Compoſition of Chalybeate Waters, may be determined by the Colours which thoſe Waters exhibit, when an infuſion of Galls is added to them.

Various other matters uſed in Medicine may, in the ſame manner, be diſtinguiſhed by the Obſervation of their Colours, and of the Changes which are producible in them. For this Method of examination is often capable of diſcovering Qualities which elude all other means.

By the Aſſiſtance of the ſame Principle, natural Philoſophy, and Chymiſtry in particular, may be conſiderably improved. I ſhall content myſelf with quoting, on this Subject, the Opinion of Henckel, a judicious Chymiſt and Philoſopher, who, though not poſſeſſed of much Knowledge in Optics, clearly perceived the Advantage ariſing from a careful Obſervation of the Colours of ſuch Subſtances as were the ſubjects of his Examination. He has frequently profited by this Method, as appears from ſeveral parts of his Writings; and he inculcates the Uſe of it in the following paſſage, as well as in many others: "Il eſt certain que toutes les Operations de "la Chymie doivent d'abord être ſoumiſes à l'examen de nos ſens, comme je ne ceſſe de l'inculquer "à tous ceux qui s'occupent de l'etude de la Nature, leur repétant continuellement que pour faire "des Découvertes il faut que dans leurs Experiences ils ſe ſervent de leurs Yeux."

I hope that, in theſe reſpects, ſome Utility may ariſe from this Inquiry: which has been carried on with a view of obtaining that End, as well as of eſtabliſhing the philoſophical Principle, which was the Object of my Experiments.

I ſhall not attempt to excuſe the Defects of the following Work, by alledging, according to the Cuſtom of many Authors, my Want of Time or Attention in the purſuit of it. On the contrary, I can aſſure the Reader that, if I have failed to produce ſuch Diſcoveries as may be worthy of his regard, I have nevertheleſs, with ſome Diligence, endeavoured to offer to his peruſal the beſt Information which I was able to furniſh: as I have employed many of my leiſure hours in making

king theſe Experiments and Obſervations, together with others relative to Optical Reſearches: which, on account of their Number, as well as of ſome Difference in their Subjects, I ſhall divide into ſeparate Papers, and reſerve for future Publications.

ADDENDA.

Preface, p. lxii. l. 23.

AFter the words *among theſe are,* inſert *the production of the Sedative Salt, which our Chymiſts are not able to analyſe or compoſe.*

P. 30. l. 13. For *this Lixivium,* read *the Alcaline Lixivium.*

P. 41. After l. 6. inſert *Although a Blue is moſt eaſily produced, by animal inflammable matter; yet, in ſome caſes, a mixture of Vegetable Phlogiſton, with thoſe Ingredients, affords that Colour.*

AN EXPERIMENTAL INQUIRY

INTO THE

CAUSE of the CHANGES of COLOURS in OPAKE and COLOURED BODIES.

A FEW detached experiments, relative to the Changes of Colour produced by the mixture of different liquors or other ſubſtances, are to be found in the writings of ſome Chymical and Philoſophical authors, and thoſe experiments are frequently exhibited in lectures of natural Philoſophy. The Inference uſually drawn from them is, that *Some change* is made by ſuch mixtures in the *Texture* of the bodies whoſe Colour is Altered; but *what kind of change* is produced in their texture has not ever, I believe, been inquired into.

Mr. Boyle, in whoſe writings are moſt of thoſe experiments which have been ſo often repeated without any conſiderable addition to their number, or any explanation of them, calls this a *Secret change of Texture.* (1)

Nothing ſhews in a ſtronger light the little attention that has been paid to this ſubject, than that the experiments and obſervations relative to it have been almoſt intirely confined to the Changes produced by Acid and Alcaline liquors on Blue and Purple flowers; and even thoſe experiments will appear in the courſe of this Inquiry to have been made in ſo defective and inaccurate a manner, that inſtead of leading to the explanation of the effects, they ſeem totally inconſiſtent with the laws of Opticks. And though I have collected many of the Experiments upon Animal and Mineral Subjects from different Authors, yet few, if any of them, have hitherto been applied to Optical inquiries.

Two obſervations only are to be found in Sir Iſaac Newton's Opticks relative to any Change of Colour in *Permanently Coloured* Bodies, the one on the Colours which Green Vegetables paſs through when they wither, the other on the Change of Colour produced by Acids or Alcalies upon Sirop of Violets. I have inſerted both theſe in their proper Places, and it will appear that what he has ſeemed to conjecture as the cauſe in theſe two inſtances only, has been applied in this paper to ſubjects as well *Animal* and *Mineral* as *Vegetable*. Had Sir Iſaac Newton been in poſſeſſion of a ſufficient Number of experiments, the cauſe which ſeems univerſally to operate the Change of Colours in Opake and Coloured bodies would, I doubt not, have been obvious to him.

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(1) Shaw's Boyle — Vol. 2. p. 51.

Out of a great number of Experiments which I was obliged to make in this Inquiry, I have ſelected ſuch only as were abſolutely neceſſary, in order to avoid prolixity.

Sir Iſaac Newton has ſhewn that " tranſparent " Subſtances, as Glaſs, Water, Air, &c. when " made very thin by being blown into Bubbles, " or otherwiſe formed into thin Plates, do exhibit " *various colours, according to their various thinneſs*, although at a greater thickneſs they appear " very clear and colourleſs." (2)

He has in the following table (3) expreſſed the thickneſs of Air, Water, and Glaſs, at which each colour is produced. Thoſe thickneſſes are expreſſed in parts of an inch divided into 1,000000 equal Parts.

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(2) Newton. Opt. Lib. 2. Part 1. 168. (3) Opt. Lib. 2. Part 2.

The thickneſs of coloured Plates and Particles of

		Air.	*Water.*	*Glaſs.*
Their Colours of the firſt Order,	Very Black	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{10}{31}$
	Black	1	$\frac{3}{4}$	$\frac{20}{31}$
	Beginning of Black	2	$1\frac{1}{2}$	$1\frac{2}{7}$
	Blue	$2\frac{2}{5}$	$1\frac{4}{5}$	$1\frac{11}{20}$
	White	$5\frac{1}{4}$	$3\frac{7}{8}$	$3\frac{2}{5}$
	Yellow	$7\frac{1}{9}$	$5\frac{1}{3}$	$4\frac{3}{5}$
	Orange	8	6	$5\frac{1}{6}$
	Red	9	$6\frac{3}{4}$	$5\frac{4}{5}$
Of the ſecond Order,	Violet	$11\frac{1}{6}$	$8\frac{3}{8}$	$7\frac{1}{5}$
	Indigo	$12\frac{5}{6}$	$9\frac{5}{8}$	$8\frac{2}{11}$
	Blue	14	$10\frac{1}{2}$	9
	Green	$15\frac{1}{8}$	$11\frac{1}{3}$	$9\frac{5}{7}$
	Yellow	$16\frac{2}{7}$	$12\frac{1}{5}$	$10\frac{2}{5}$
	Orange	$17\frac{2}{9}$	13	$11\frac{1}{9}$
	Bright Red	$18\frac{1}{3}$	$13\frac{3}{4}$	$11\frac{5}{6}$
	Scarlet	$19\frac{2}{3}$	$14\frac{3}{4}$	$12\frac{2}{3}$
Of the third Order,	Purple	21	$15\frac{3}{4}$	$13\frac{11}{20}$
	Indigo	$22\frac{1}{10}$	$16\frac{4}{7}$	$14\frac{1}{4}$
	Blue	$23\frac{2}{5}$	$17\frac{11}{20}$	$15\frac{1}{10}$
	Green	$25\frac{1}{5}$	$18\frac{9}{10}$	$16\frac{1}{4}$
	Yellow	$27\frac{1}{7}$	$20\frac{1}{3}$	$17\frac{1}{2}$
	Red	29	$21\frac{3}{4}$	$18\frac{5}{7}$
	Bluiſh Red	32	24	$20\frac{2}{3}$

I have here placed as much of Sir Iſaac Newton's Table as is neceſſary for the explanation of this

Paper: in the latter part of the table, which I have here purpoſely omitted, the Colours are blended ſo as to become indiſtinct.

After having ſhewn by a great many experiments made with *Tranſparent Colourleſs ſubſtances,* ſuch as Glaſs, Water, and Air, that " their Thin tranſ-" parent Plates, Fibres and Particles do according " to their ſeveral Thickneſſes, reflect ſeveral ſorts " of Rays, and thereby appear of ſeveral Colours," he draws from thence this conſequence, " that no-" thing more is requiſite for producing all the " colours of *natural bodies,* than the ſeveral Sizes " and denſities of their Particles." (4)

" That the Tranſparent parts of bodies accord-" ing to their *Several Sizes* muſt reflect rays of " one colour, and tranſmit thoſe of another, on " the ſame grounds that thin Plates or Bubbles " do reflect or tranſmit thoſe rays — and this " he takes to be the ground of all their Co-" lours." (5)

All the experiments which have hitherto been made, were performed with the above-mentioned *Colourleſs* Tranſparent ſubſtances: and although the Colours of *Permanently Coloured* bodies are attributed by Sir Iſaac Newton to the ſame cauſe, by which they were produced in Colourleſs ſubſtances, viz. to the Various Thickneſſes of their component Particles; yet no experiments have as yet been made on *Permanently Coloured* bodies in order to eſtabliſh the truth of Sir Iſaac Newton's opinion, which therefore has hitherto remained merely ſpeculative and uneſtabliſhed by any Proofs.

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(4) Newton. Opt. Lib. 2. Part 3. Prop. 10. (5) Ib. L. 2. Part 3. Prop. 5.

To illuſtrate that Opinion, and to eſtabliſh the following Theory reſulting from it, viz. that the *Changes* of Colour in *Permanently Coloured* bodies are made according to the ſame Law, which is ſhewn by Sir Iſaac Newton's experiments to have taken place in *Pellucid Colourleſs* ſubſtances; I have made ſeveral experiments and, beſides thoſe, I have introduced ſuch Proceſſes of Chymiſtry, Dying, and other Arts as were neceſſary to explain the Changes which are made in the Colours of natural bodies.

It appears from the experiments of Sir Iſaac Newton, as well as from the table p. 4. that *the Leſs Refrangible* colours are exhibited by the *Greater thickneſſes of* Air, Water, and Glaſs: and that as the thickneſs of thoſe Subſtances is diminiſhed, they reflect the more refrangible colours: ſo that as the thickneſſes of thoſe media in the table Decreaſe as they Aſcend, their correſpondent colours proceed in Aſcending from Red to Orange, Yellow, Green, Blue, Violet, and ſo on to the Red of the Order next above.

From the Obſervation of theſe circumſtances, it appeared to me that, if *Permanently Coloured* bodies are ſubject to the ſame laws as *Tranſparent Colourleſs* ſubſtances are, all ſuch *Permanently* Coloured bodies, whenever the Size of their Particles is *Diminiſhed*, ſhould undergo a change of colour by Aſcending from the leſs refrangible to the more refrangible colours, and from thence to the colours of the Order next *Above*: and that ſuch bodies, when the *Size* of their particles is *Augmented*, ſhould undergo a contrary Change, their Colours in this caſe *Deſcending* from the More refrangible colours to the Leſs refrangible, and from thence to the Colours of the Order next *Below*. (6)

To elucidate this I found it neceſſary to make experiments with Vegetable, Animal, and Mineral ſubjects whereby the *Size* of their Particles, upon which their Colours depend, might be *Diminiſhed* or *Increaſed*.

The methods which I uſed in order to diminiſh the Size of the particles of thoſe bodies which were the ſubjects of inquiry, were by *Diſſolving*,

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(6) I have throughout this paper uſed the word *aſcend* to expreſs the Changes of Colour from the Leſs to the More refrangible colours of one Order, and from thence to thoſe of the Order of colours next above: The word *deſcend* I have uſed in the contrary ſignification. Theſe words refer to the Local poſition of the Colours in the Table p 4. they appeared to me the cleareſt and ſhorteſt expreſſions applicable to the Changes of Colour which I here treat of.

Attenuating, &c. by means of Chymical Solvents, Heat, Putrefaction, Dilution, &c.

The contrary effects were brought about by ſuch means as are known to *Condenſe*, *Incraſſate*, or Unite the Particles of bodies into *Larger maſſes*, as by Coagulation, Precipitation, Evaporation, by *Diminiſhing* the force of the ſolvents, &c.

The following Experiments and Obſervations were made upon Vegetable, Animal, and Mineral Subſtances, each of theſe affording numerous inſtances of Changes of Colour which illuſtrate the Theory.

Experiments upon Vegetable Subſtances.

THE Colouring particles are in a State of Solution in the juices of Vegetables, while they are growing. Thoſe juices containing the colouring particles are capable of being expreſſed from ſeveral berries and fruits; and the coloured juices of leaves and flowers, though generally leſs in quantity, may be imparted to paper, cloth, &c. by bruiſing them on thoſe ſubſtances.

It appears from a chymical examination, that all Vegetables, and every Part of them, contain an Acid.

1) When Burned in the open air they emit a ſmoke ſtrongly impregnated with Acid. (7)

2) This Acid may be received in veſſels, when the Vegetables are diſtilled by a ſtrong fire. (8)

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(7) Neumann's Chym. by Lewis, p. 463. Vegetables burnt in the open air, emit a copious *Smoke*, which is manifeſtly impregnated with *an Acid*, &c.——Into thoſe principles, *all Vegetables*, and their Parts, and *all* the Subſtances extracted from Vegetables, are reſoluble.

Boerhaave Chym. Proceſs 32. — We hence learn the nature of that primary ſmoky vapour, which exhales from green wood laid upon the fire, before the wood begins to grow black, take flame, or ignite... For thus there exhales an *Acid*, acrimonious, *water*, offenſive to the eyes, and capable of penetrating and preſerving ſuch animal fleſh as is ſuſpended in the chimney where this vapour riſes; and a liquor extremely like it is collected at both ends of a long piece of green wood, laid with it's middle upon the fire; which thus drives out a *tartiſh* water, with a hiſſing noiſe.

2. We learn the nature of the firſt ſmoky vapour, which ariſes from dry wood when applied to the fire, or from green wood after the former liquor is driven off, tho' before the wood begins to ignite or burn; for this ſmoke is thicker, *more* acrimonious, *acid*, and ponderous than the former, containing more *acid ſalt*, and beginning to grow ſomewhat black.

3. Hence again we learn the nature of that black, groſs, and keep Smoke which riſes from wood thrown upon live coals, a little before it burſts out into flame; for this ſmoke contains a very ſharp, fixed, and *Copious Acid ſalt*, together with the 1ſt, 2d, and 3d, pitchy Oil of our proceſs, all compounded and mixed together; which makes a vapour intolerably pungent to the eyes; and this alſo penetrates the bodies expoſed thereto, preſerves them by its Acid Salt, &c.

(8) Boerhaave Chym. Proceſs 15. The common diſtilled water of a freſh Plant, by the Alembic — Let the due degree of heat be

3) The ſame Acid is found alſo in the Oils, Spirit, Tartar and Vinegar procured from Vegetables.

When Plants are dried, their watery parts are diminiſhed, but it appears from the chymical analyſis of them that the Acid remains, together with the

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be carefnlly obſerved, and equally kept up, ſo long as the water diſtilling into the receiver proves white, thick, odorous, ſapid, frothy and turbid; for this water ſhould be kept carefully ſeparated from that which will follow it; — for there afterwards riſes a water that is tranſparent, thin and without the peculiar taſte and odour of the plant, but generally ſomewhat *tartiſh* and limpid, tho' ſomewhat obſcured and fouled by white dreggy matter; and if the head of the ſtill be not tinned, the *Acidity* of this laſt water cauſes it to diſſolve the copper, ſo as to become green, nauſeous, emetic, and poiſonous to thoſe who uſe it. — The Water of the 2d running wants the volatile part above deſcribed, yet ſcarce brings over the more fixed part of the plant, except what is ſomewhat *Acid* and vapid: If when this is come off, freſh water be poured upon the remaining plant, and boiled therewith, or ſtrongly diſtilled, there riſes a *more Acid Water*, containing very little of the particular virtue of the plant; almoſt the *ſame kind of Acidity* appearing thus to riſe from *them All* at laſt.

Boerhaave Chym. Proceſs 32. Diſtillation therefore performed in cloſe veſſels extracts theſe volatile parts from vegetables; viz. a water, a Spirit, an *Acid Salt*, two kinds of oil, &c. — This experiment is Univerſal or holds in *All* trees, ſhrubs, and moſt herbs, which, when thus treated, afford all theſe fixed and volatile parts; for they *All* contain *a volatile Acid Salt*, &c. ———

Macquer Elemens de chymie. tom. 2. p. 156.

Preſque toutes les plantes qui fourniſſent de l'alcali volatile dans la diſtillation, fourniſſent *auſſi une aſſés grande quantité d'Acide*.

the Colouring particles and the other component principles, in a ſolid form: In this ſtate are the Woods, &c. uſed in Dying.

This obſervation of the exiſtence of an Acid in Vegetable ſubjects ſuggeſted to me the propriety of diſſolving their Colouring particles in an Acid Liquor, in Imitation of their Natural ſtate, whilſt in the growing Vegetables.

I uſed this method in order to be certain of the nature of the Menſtruum, by which the Colouring particles were diſſolved in the following Experiments.

The Acid Liquor, in which I diſſolved the Colouring parts of the Vegetables, conſiſted of Water with about an eightieth part of Aqua Fortis. This I found better ſuited to theſe Experiments than the other Mineral or Vegetable Acids: and I have called it the *Acid Liquor* in the following pages.

When I intended to *Diminiſh* the diſſolving Force of this Acid Liquor, I added gradually to it a ſmall quantity of a Solution of Pot Aſh or ſome other *Alcaline* liquor.

The Order of the Experiments upon Vegetables is that of the primary colours in the table p. 4. beginning with the Red, and proceeding next to the Purple, Blue, Green, and Yellow. The changes produced in every one of them agree exactly with the Theory: for in each experiment as the Strength of the Menſtruum by which the Colouring particles were diſſolved is *Increaſed* or *Diminiſhed*, whereby they are Attenuated or Incraſſated, the Colours *Aſcend* or *Deſcend* regularly.

Changes of Colour in Red Vegetable ſubſtances.

FROM a variety of Red Flowers, in the Colour of which there was no admixture of blue, I extracted the Colouring particles, by infuſing them for ſome hours in the Acid Liquor. To avoid prolixity, I ſhall only mention the following, *viz.*

Red Balſam
Red Poppy
Scarlet Lychnis
Scarlet Kidney Bean
Monarda — Canada Leonurus.

The Solution of the Colouring particles of theſe Flowers in the Acid Liquor was *Red*. When the diſſolving Power of the Liquor was weakened, by the addition of a Solution of Pot-Aſh, the infuſion became Purple: If a ſtill greater quantity of that or any other Alcali is added, the Colour of this infuſion does not undergo any further Change.

If inſtead of Diminiſhing the ſtrength of the Acid Liquor by means of an Alcali, it's Force be Increaſed by the addition of a Stronger Acid, as Oil of Vitriol, the Colour inſtead of *Deſcending* from Red to Purple, *Aſcends* from Red to Yellow, thus,

Liquor in which the Colouring particles of Red Flowers are diſſolved, by the Addition of Oil of Vitriol, which attenuates —— ——	Yellow.
Liquor in which the Colouring particles of Red Flowers are diſſolved -	Red.
By the addition of an Alcali, which Incraſſates —— ——	Purple.

The ſame Changes are made in the Colours of the *Red* Woods by the ſame means, thus the *Red* infuſion of Brazil, (9) and Logwood, (10) are turned *Purple* by Alcalies, and Yellow by Acids.

The *Red* juice of Currants, &c. by the addition of Alcalies become *Purple*, and by Oil of Vitriol *Yellow*.

Changes of Colour in Purple Flowers.

THE following are ſome of the Purple Flowers from which I extracted the Colouring particles, by means of the Acid Liquor. (Under the name of Purple I include all thoſe which have any admixture of Red and Blue.)

Purple Iris,
Bee Larkſpur
Aconite—Monkshood,
Purple Garden Pea,
Panſie,
Sweet Williams,
Pink,
Veronica.

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(9) Shaw's Boyle, vol. ii. p. 83.

(10) Ib. p. 52, 80, 83.

The Colouring particles of theſe Flowers in the Acid Liquor exhibited a *Red* colour, with little or no admixture of Blue.

The Change produced in this *Red* liquor, by the Gradual addition of an Alcali, is very different from that which has generally been deſcribed; for it has been ſuppoſed that the Flowers of this Colour are *immediately* Changed into *Green* by an *Alcali*; whereas, by that addition, the Colour of this Red infuſion deſcends, through all the gradations of Purple, Violet, and Blue, before it exhibits a Green. (11)

The operations of Nature, and thoſe which are contrived in imitation of them will, when thoroughly underſtood, be found regular and conformable to ſtated Laws; but a Tranſition from one of the primary Colours to another which in the Order of Colours is diſtant from it, without paſſing through the intermediate gradations, would be an irregularity inconſiſtent with the Laws of Opticks.

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(11) The following is one of the two obſervations of Sir Iſaac Newton, which I have before referred to. "Blues and "Purples may be either of the ſecond or third order, but the "beſt are of the third. Thus the colour of *Violets* ſeems to be "of that order, becauſe their *Sirup* by *acid* Liquors *turns* red, and "by *urinous and alcalizate* turns *green*. For ſince it is of the "nature of *Acids* to *diſſolve* or *attenuate*, and of Alcalies to "*precipitate* or *incraſſate*, if the purple Colour of the Sirup was "of the ſecond Order an acid Liquor by attenuating it's tinging "Corpuſcles would change it to a red of the firſt order, and an "Alcali by incraſſating them would change it to a green of the "ſecond order; which red and green, eſpecially the green, "ſeem too imperfect to be the colours produced by thoſe "Changes. But if the ſaid purple be ſuppoſed of the third "order, its Change to Red of the ſecond, and Green of the "third, may without inconvenience be allowed." Opt. Lib. 2. Part. 3 Prop. 7.

In the Liquor prepared from moſt of the Purple flowers all the Colours are very vivid and beautiful.

By the addition of Oil of Vitriol the Red *Aſcends* to a *Yellow.*

If any of the *intermediate* Colours between Red and Green be wanting in the Experiment, it is a Proof that too much Alcali has been added at once; which Fault is eaſily corrected by the *gradual* addition of Aqua Fortis: For when by the *gradual* addition of an Alcali the Colours have Deſcended through every gradation from Red to Green, they may be made, by the addition of Aqua Fortis, to aſcend through the ſame gradations, but in a Contrary Order: and this Experiment may be repeated backwards and forwards, as often as is deſired, without any of the Colours being the leaſt impaired.

Thus all the primary Colours are exhibited in their regular Order, from the Colouring particles of one and the ſame Flower, by merely *Increaſing* or *Diminiſhing* the Force of the Menſtruum in which they are diſſolved:

The Colouring particles of Purple Flowers diſſolved in the Acid Liquor, by the addition of the Oil of Vitriol, - - -	Yellow.
The Colouring particles of Purple Flowers diſſolved in the Acid Liquor - - -	Red.
Colours gradually produced in this infuſion by the addition of an Alcali,	Purple, Violet, Blue, Green.

From the facility with which the colours, that by the Alcali were carried Downward, are by an Acid made to Reaſcend without being impaired, it appears that the Colouring particles are not deſtroyed in this Experiment, but only united into larger Maſſes by the Alcali, and Divided into Smaller, by the Acid.

But when, by the addition of a ſtronger Acid, the Red is changed to a Yellow, the particles ſeem to have their Texture deſtroyed, for they can not afterwards be made to exhibit any other primary Colour by the addition of an Alcali.

Amongſt all the Changes of Colour which I have been able to produce in any ſubject whatſoever, I have never found that a Primary Colour changes immediately into any other, than that which lies next to it in the regular Order of Colours.

But in making Experiments with ſome Purple Flowers, not mentioned in the above liſt, an extraordinary circumſtance appears: Though the *Red* infuſion of them is bright and full, as well as the Green into which it is changed by the Alcali, yet the *intermediate Blue,* and the Colours on its confines, as Violet, &c. are ſo very dilute, that in their room, the infuſion is almoſt Tranſparent and Colourleſs, leaving as it were, a Colourleſs gap in the gradation of Colours between the Red and Green, thus,

Liquor in which the Colouring particles of Roſe Campion, &c. were diſſolved,	Red.
Colours produced in this Red infuſion by the Gradual addition of an Alcali, - - -	Faint Purple. Colourleſs Tranſparent Liquor. Green.

But though in ſome Flowers this faintly coloured or colourleſs gap intervenes between the Red and the Green, I have not met with any Inſtance of a ſudden Change from *Red* to *Green,* without either the interpoſition of a bright vivid *Blue,* which is moſt common, or the faint or *Colourleſs gap* interpoſed in the place of the Blue.

From this Circumſtance of Inviſibility and Tranſparency in the Colouring particles, it ſeems that when they are reduced to a certain ſize with relation to the parts of the liquor in which they are ſuſpended, in that caſe they exhibit no degree of opacity nor Colour: but when their ſize is either Increaſed or Diminiſhed, they become viſible and coloured. The ſame circumſtance is very commonly ſeen, when the Flowers have been ſteeped in Spirit of Wine, Water, &c. to which no Acid had been added; for though thoſe liquors are then Colourleſs and Tranſparent, yet it is evident that the Colouring particles are diſſolved in them, becauſe the addition of an Acid or Alcali will produce Colours in thoſe Liquors, which before ſuch addition were colourleſs.

I have found many other Inſtances of the ſame kind in the Experiments which I have made; I ſhall not here enter farther into the Explanation of this Appearance, nor has it hitherto, I believe, been remarked or explained by any one.

Changes of Colour in Blue Flowers.

WHEN the Colouring particles of Blue Flowers as,

Convolvulus,
Blue Lupine,
Spiderwort,
Borrage, &c.

were diſſolved in the Acid Liquor, it put on exactly the ſame appearance as that in which the Purple Flowers were infuſed, and all the Experiments made with this this Red liquor were ſimilar to thoſe made with the infuſion of Purple Flowers.:

From theſe circumſtances it ſeems probable that the Colouring particles of the *Purple* and the *Blue* Flowers are of one and the *ſame ſort*, only differing in *Size*, as they are divided into Greater or Leſs maſſes, by the Greater or Leſs quantity of Acid prevailing, either in the Plant while it is Growing, or added in the Experiment. On the ſame Plant both *Purple* and *Blue* Flowers are frequently found, and the Blue Flowers often change to Purple, and *vice verſâ*, ſo that all the Gradations betwen Red and Blue are common to them; the Change of Colour appearing to be brought about by Natural means, with the ſame facility as in the Experiments made Artificially with them.

The *Red* Flowers, in which there is no admixture of Blue, are found by experiment incapable of being changed to Blue, as the Purple ones are: and the ſame incapacity of undergoing ſuch a Change is conſtantly found in *thoſe Flowers* whilſt they are *Growing*, as they never are, whilſt Growing, of any Colour but Red, nor do they in withering Change to any Colour but Purple.

Thus it appears that, notwithſtanding the Variety of theſe ſorts of Experiments, the effects produced by them are ſuch as take place in the natural Proceſs, which ſuch Bodies are conſtantly undergoing while they vegetate. And our endeavours will generally prove vain, when we attempt, in Optical Inquiries on Colours, to produce Effects different from thoſe which Nature itſelf operates. It is by an imitation of Nature, in this as in all other Sciences, that Succeſs is principally to be hoped for.

All theſe Experiments may be made with the Flowers themſelves inſtead of their Infuſions, but with more difficulty and inconvenience, becauſe the other Solid parts of the petals acted upon, as well as the colouring particles, confuſe the Experiment. The Colouring particles when diſſolved in the Acid Liquor, being pure and unmixed with the other parts of the Flowers, the Experiments performed with them are capable of being repeated with much greater eaſe and accuracy.

Changes of Colour in Green Vegetable ſubſtances.

THE *Green* parts of Vegetables as their Leaves, Unripe Berries and Fruits, do not eaſily undergo a Change of Colour by the application of Acid or Alcaline liquors: But by the Gradual *Diminution* of the Acid contained in them, or by the Condenſation of their parts, their Colours Change from Green to Yellow, Red, Purple, &c. Deſcending in the Order of Colours, from the ſame Cauſe and according to the ſame Law, which is obſerved by the other coloured Vegetable Subſtances.

The Berries and Fruits in their moſt Acid ſtate are generally *Green*, from which Colour many of them as Currants, Cherries, Plums, &c. in proportion as they ripen, *Deſcend* regularly, according to the Order of Colours, through all the gradations of Green, Yellow, Red, and ſometimes

Purple; while their Acid evidently decreaſes, in proportion as thoſe Changes take place.

In many Fruits as Apples, Peaches, &c. that ſide only which is moſt ripened, by its expoſure to the Sun, becomes Red, the other parts remaining Yellow or Green, the Green part ſtill continuing Acid.

When Leaves wither, their Colouring particles accede together and become united into Larger Maſſes, by the exhalation of the Acid and watery parts, in which they were diſſolved. For when thus dried by the Sun and in the open air they are found, by a chemical examination, to have loſt their acid, and to have become effete. In proportion as the water and acid which kept the Colouring particles of the Leaves in a State of Solution evaporates, their Colours Deſcend in a regular gradation. Thus Sir Iſaac Newton in one of the two paſſages, which I before mentioned, has obſerved, Opt. Lib. 2. Part 3. Prop. 7. "When "Vegetables Wither, ſome of them turn to a "Greeniſh Yellow, and others to a more perfect "Yellow or Orange, or Perhaps to Red, paſſing "firſt through the aforeſaid intermediate Colours; "Which Changes ſeem to be effected by the "exhaling of the moiſture which may leave the "tinging Corpuſcles more denſe, and ſomething "augmented by the accretion of the oily and "earthy parts of that moiſture."

2, The Green Leaves of the Anil and Glaſtum by a contrary proceſs, undergo a Change of Colour, in a contrary Order, for by being long ſteeped in Water their parts are diſſolved into a *Blue* ſubſtance which is Indigo and Woad.

And it is probable that other Plants may be diſcovered whoſe Leaves may undergo the ſame change by a ſimilar method of Attenuation.

Change of Colour in Yellow Vegetable ſubſtances.

I do not find that any Experiments have hitherto been made with relation to the Change of Colour which may be effected in Yellow Flowers. However I have obſerved that the ſame effect is eaſily produced in them, from the ſame proceſs by which the Colours of the other Flowers were affected, their Colour *Aſcending* to *Green* by the application of an Acid.

The following Yellow Flowers having been ſteeped for Some days in a mixture of water and Aqua Fortis, were changed to a Green Colour not diſtinguiſhable from that of Graſs or the Green Leaves of Vegetables:

Yellow Cinquefoil
Cryſanthemum
Butter Cups — Ranunculus pratenſis
Yellow Jaſmine
Yellow Thiſtle
Yellow Lupine

Many of theſe Yellow Flowers are changed immediately into a vivid Green, by the application of a drop of undiluted Aqua Fortis.

Some Yellow Flowers do not undergo a Change of Colour by the Addition of an Acid; but I have not found that any Colour, excepting Green, can be produced by an Acid from any Yellow Flower.

The infuſions of Rhubarb, &c. are by the addition of an Alcali made to Deſcend from Yellow to Orange and Red.

Experiments upon Animal Subjects.

THE Changes of Colour which Animal ſubſtances undergo, ariſe from the ſame cauſe, by which the Colours of Vegetables are affected; ſo that the ſame Principle ſeems to be common to both under ſimilar circumſtances. Several Animal ſubſtances being ſubject to a change of Texture from ſuch Cauſes as *Attenuate*, viz. *Heat*, *Menſtrua*, *Putrefaction*, &c. or from the contrary proceſſes, which *Incraſſate*, as *Coagulation*, *Evaporation*, &c. are ſubject to a Change of Colour in proportion as they are affected by ſuch proceſſes.

Of this nature are the Shells of Lobſters, Cray Fiſh, Prawns, &c.

Changes of Colour in Shells.

THE Shells of Lobſters, when alive, are of a *Blue* Colour which, though often ſo intenſe as to be uſually called Black, are not uncommonly of a light and very fine *Blue*.

The Change which they undergo, when boiled, appeared to me to ariſe from their *Attenuation* by *Heat,* which is known to ſeparate the parts of bodies: and I have obſerved that ſo ſmall a Heat, as that of the Sun, will completely change thoſe *Blue* Shells into *Purple* and *Red,* which are the Colours *next* in the Order *above the Blue*.

From the known Alcaline quality of theſe Shells I was induced to try whether I could not, by Solution in an Acid, produce the ſame Red Colour which is uſually effected by Heat.

For this purpoſe I ſteeped the Blue Shells of Lobſters in Aqua Fortis, by which means their Colour was changed to Purple, Red, and Yellow.

The Shells of Cray Fiſh alſo, after I had ſteeped them in Aqua Fortis or Spirit of Salt, were changed into a Red not diſtinguiſhable from that produced by Boiling them: By a longer continuance in either of thoſe Acids the *Red* was farther changed into *Yellow*.

The *Red* parts of the Shells of Prawns, by the ſame treatment, became alſo of a beautiful *Yellow*:

Shells of Lobſters by a longer Continuance in an Acid —	Yellow.
Shells of Lobſters ſteeped in an Acid — — —	Red Purple
Shells of Lobſters — —	Blue

Changes of Colour in Milk.

IF freſh Cow's Milk be *coagulated*, by dropping Oil of Tartar into it gradually, while it is boiling, it's Colour paſſes through every gradation of Yellow, Orange, and Red, in proportion as the Liquor is Coagulated into a Thicker maſs. (12).

It is conſtantly obſerved that Milk when *diluted* with Water, by that Method of *Attenuation*, becomes Bluiſh.

Thus from one and the ſame Liquor, the five firſt Colours of Sir Iſaac Newton's table are produced in their regular Order, in proportion as the component parts of it are united into Larger maſſes.

Cow's Milk diluted with Water	Bluiſh.
Cow's Milk	White.
Cow's Milk Coagulated by Alcali	Yellow.
Cow's Milk farther Coagulated	Orange. Red.

See the Colours of the firſt Order in the Table, with which theſe exactly correſpond.

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(12) Boerhaave Chym. Proceſs 91.

Recent Cow's milk *Coagulates*, turns *Yellow*, and *Red*, by boiling over the fire with fixed Alcali.

Dilute new cow's Milk with a little water, boil it in a clean veſſel, and by degrees drop oil of tartar per deliquium into it; it will thus

Changes of Colour in Blood.

ALL the Animal humors become thinner, and are reſolved by Putrefaction. The *Yellow* Serum of the Blood, according to Sir John Pringle, is by Putrefaction changed to *Green*, and the Greenneſs obſervable in ſalted Meats, as well as in the Putrefied parts of Animals, is aſcribed by him to Putrid Serum. (13)

The *Red* Craſſamentum, by long expoſure to the air becomes Yellow. (14) The Colour in each caſe *Aſcending* one degree by this means of Diſſolution.

Changes of Colour in Bile.

THE Bile differs conſiderably from the other Animal Fluids in this reſpect, that even when Recent it is Alcaline. It appears from a Memoir of Mr. Cadet, Acad. Sci. Ann. 1767, that it contains a quantity of the Foſſil Alcali.

From the Alcaline quality of the Bile, I was induced to think that the addition of an Acid would *Diſſolve* or *Attenuate* it.

1. Having

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thus begin to turn *Yellow*, the more ſo as *more* Alcali is added, and the boiling the longer continued, ſo as to *paſs* from a *faint Yellow* into a *Red Colour*.

At the ſame time it *coagulates more and more*, and ſeparates into curdy maſſes, though not ſo large and firm, nor ſo eaſily hardening, as thoſe produced by acids. At length by *boiling* the whole long enough, it becomes a *Thick*, *Red*, *Coagulated* Maſs.

(13) Pringle, *Diſeaſes of the Army*, Append. p. 80.

(14) Boerhaave, Chym. Proceſs 114.

1. Having therefore procured ſome Freſh Bile of an Ox, which was *Yellow* without any admixture of Green; to an ounce of this Bile I added a tea-ſpoonful of Spirit of Salt, which immediately changed it's *Yellow* Colour into *Green*, the ſame change was effected by Aqua Fortis. I find that Baglivi and others have remarked that Acids produce this effect. (15.)

2. To examine the effect of *Attenuating* this Bile by *Heat*, I expoſed a part of it, while freſh, to a degree of Heat leſs than that of boiling water, for a quarter of an hour, and found that by this means it's *Yellow* Colour was changed to *Green*, though no ſenſible evaporation had taken place. This Change is ſimilar to that which is effected by Heat in the Shells of Lobſters, the Colour in each caſe *Aſcending* one degree from the ſame cauſe.

3. To try the effect of *Putrefaction* in Diſſolving and Changing the Colour of the Bile, I left ſome of it ſtanding in the open air in a glaſs veſſel, and I obſerved that it changed gradually from *Yellow* to a *Green*, *ſimilar* to that which was produced by *Heat* or the addition of an *Acid*.

Changes of Colour in Urine.

WHEN freſh Urine is Incraſſated by diſtilling from it the Watery part, " the remaining Urine, " in

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(15) Neumann's Chym. by Lewis, p. 567.

" in the mean time, gradually Changes from it's " natural *Straw Colour* to *Red,* and the more of " this *pellucid water* comes over, the deeper that " *Red* Colour appears." Boerhaave, Chym. Proceſs 93.

The remaining *Red* liquor is not either Alcaline or Acid.

Thus by merely Incraſſating the Urine by means of Evaporation, it's *Yellow* Colour is made to *Deſcend* gradually to *Orange* and *Red.*

Experiments upon Mineral Subſtances.

THE Metals afford numerous inſtances in confirmation of the doctrine already explained; for almoſt every operation, to which they are ſubjected exhibits a Change of Colour perfectly agreeing with the Law which we have obſerved in Vegetable and Animal Subſtances.

The imperfect Metals afford the greateſt variety of theſe inſtances, as their Texture is liable to many Changes, accordingly as they are acted on in different operations: for every Change of their *Texture* is accompanied by a correſpondent Change of *Colour.*

I ſhall endeavour to illuſtrate this, in the firſt place by conſidering the numerous Changes of *Texture* and *Colour* to which Iron is ſubject, and by ſhewing the agreement of *Texture* with the Change of *Colour* in that Metal.

Changes

Changes of Colour in Iron.

IRON diſſolved in the Vitriolic Acid, diluted by a ſufficient quantity of Water, and afterwards Cryſtallized, forms *Green* Vitriol of *Iron.*

When this *Green* Vitriol is expoſed to a ſtrong heat, the Acid Menſtruum is driven off from it, in form of Spirit and Oil of Vitriol, and in proportion as the Iron *parts* with it's Acid *Solvent,* it's Colour *Deſcends* from *Green* to *Yellow, Red* and *Purple.* (16)

Theſe

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(16) Neumann's Chym. by Lewis, p. 179. Vitriol of Iron — On urging it with a *ſtronger* fire, *Acid* Fumes ſucceed the watery ones, the matter becomes *Yellow, Red,* and at length of a deep *Purpliſh Red.*

I have not, amongſt the Colours, which ariſe from the diſcharge of the Acid Solvent, mentioned the Whiteneſs and Opacity which Vitriol aſſumes when expoſed to a gentle heat: becauſe thoſe appearances are not occaſioned by the diſcharge of the Acid Menſtruum, but by the evaporation of the Water only. Both the Opacity and Whiteneſs are cauſed by the diſcontinuity of the parts of the Vitriol, for the Water being evaporated leaves the Pores which it has forſaken either empty or repleniſhed with Air, which is a Medium of a different denſity from the other parts of the Vitriol. Sir Iſaac Newton has given ſeveral Inſtances of Whiteneſs and Opacity ariſing from this cauſe: (17) “ The moſt tranſparent Subſtances may, by “ evacuating their Pores, or ſeparating their parts, be ren“ dered ſufficiently Opake, or *Salts* or wet paper, or the Oculus “ Mundi Stone by being dried, Horn by being Scraped, Glaſs “ by being reduced to Powder, or otherwiſe flawed, Turpen“ tine by being Stirred about with Water till they mix imper“ fectly, and Water by being formed into many ſmall bubbles, either

(17) Opt. Lib. 2. Part. 3. Prop. 3.

Theſe are the Colours exhibited by *Green* Vitriol in proportion as it's Solvent part is diminiſhed.

When, on the contrary, a ſtill *greater Solution* of the Iron than that which takes place in the Green Vitriol) is effected, the Colour is found to *Aſcend* from Green to *Blue*, *Purple*, and *Red.*

This ſeems to be the State of the *Iron* in the pigment called Pruſſian Blue, for the Metallic parts are *Diſſolved* and greatly Attenuated by the Alcali and Animal Phlogiſton, previous to the application of the Acid uſed in the proceſs.

As a conſiderable quantity of Pruſſian Blue is obtainable from this Lixivium, without any other addition than an Acid; the cauſe of that Blue Colour may be eaſieſt inveſtigated from the conſideration of the ſimple Lixivium, without the admixture of the other ingredients uſed in the ordinary proceſs.

It is evident that the Lixivium produces it's effect by *Diſſolving the Iron*, for if the Lixivium itſelf be examined without the addition of any *Ferruginous* or *Vitriolic* matter, it is found to have Diſſolved the Iron which was contained in the ingredients of which it was formed.

That

" either alone in the form of Froth, or by ſhaking it together " with oil of Turpentine, or oil Olive, or with ſome other " convenient Liquor, with which it will not perfectly incorporate. And to the increaſe of the opacity of theſe bodies, it " conduces ſomething, that by the 23d Obſervation the Reflexions of very thin tranſparent Subſtances are conſiderably ſtronger than thoſe made by the ſame Subſtances of a " greater Thickneſs."

That the Lixivium is a *Solvent* of the Iron in the Proceſs, and not the *Precipitant* of it as hath been generally ſuppoſed, appears from theſe circumſtances.

1. A conſiderable quantity of *Iron* is always found *Diſſolved* in the Lixivium itſelf.

2. The mineral *Acids*, which contain no Iron, *Precipitate* that metal from the Lixivium, in which it was *Diſſolved*.

In like manner it is by means of it's *Acid* that Vitriol *precipitates Iron* from the Lixivium. It is clear that the Iron contained in the Vitriol is not neceſſary to the precipitation, for the *Acid* without the Iron is, in this caſe, an effectual *Precipitant*: and that metal remains conſtantly *Diſſolved* in the Lixivium, with the Phlogiſton, when no Acid is added to it.

To a tea-ſpoonful of Lixivium, ſaturated with Pruſſian Blue in the manner deſcribed by M. Macquer, I added ſome Spirit of Salt, by which a very fine Blue was immediately produced, and this happened whether the Lixivium was diluted with Water or not.

This Experiment was repeated ſeveral times, as it ſeemed to contradict an aſſertion of M. Macquer, to whom the public is ſo much indebted for his Diſcoveries on the Subject.

From having overlooked the *Iron Diſſolved in the Lixivium*, ſome eminent Chymiſts have truſted to the Blue Colour produced by it's mixture with *Acid* Liquors, as a teſt that *Iron is contained in them*.

them. Margraf, from the application of this Lixivium to each of the mineral Acids by which a ſmall quantity of Lapis Lazuli had been diſſolved, and from the *Blue* which aroſe on the mixture of thoſe Liquors, concludes that the *Acids* had extracted a ſmall quantity of *Iron.* (18) But it is certain that the ſame Colour is produced by a mixture of the Lixivium with *Acids* which contain *no Iron.*

Independently of this proceſs it is apparent that an *Alcali*, ſuch as is uſed in the preparation of Pruſſian Blue, is capable of *Diſſolving Iron* under certain circumſtances.

Pot-Aſh and other Fixed Alcaline Salts are uſually prepared by Lixiviating in Water the Salts which are contained in the Aſhes of Vegetables, and afterwards evaporating the Solution till the Salt remains dry. *Iron* is conſtantly found *Diſſolved* in theſe *Lixivia*; and the Salt procured from them, by means of this Ferruginous mixture, communicates to Glaſs a *Green* or *Blue* Colour. A certain proof that Fixed Alcaline Salts are indued with a power of *Diſſolving Iron:* But the quantity of Iron diſſolved in Alcalies not united to an *Animal Phlogiſton*, is much leſs than that which the Lixivium uſed in the Proceſs of Pruſſian Blue diſſolves.

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(18) Margraf. Opuſc. Chym. Diſſert. 23.

Je me mis là-deſſus a éprouver toutes ces *Solutions*, chacune a part, avec la leſſive d'une calcination d'alcali avec du ſang; et en ayant ſaturé ces ſolutions, je remarquai que celle qui avoit été faite avec l'acide du nitre ſe précipitoit mieux que toutes les autres ſous une *belle couleur blue; ce qui prouve qu'elle renferme un petit nombre de particules de Fer.*

If a Solution of Iron in the Nitrous Acid be mixed with a Solution of Pot-Aſh, it becomes immediately and perfectly *Diſſolved* by that Alcali. (19) I have in the ſame manner applied a Solution of Vitriol, as I ſhall relate hereafter.

It is obſervable that neither the Iron which is found Diſſolved in Alcaline Salts, nor that which is communicated to Alcaline Lixivia by the admixture of Solutions of Iron in Acids, produces a Blue Colour: this will be proved to depend on the Abſence of an Animal Phlogiſton; as will appear from the conſideration of the Pruſſian Blue, and from ſeveral other Inſtances, in all of which I ſhall ſhew that the preſence of an *Animal Inflammable Principle*, United to ſuch other Ingredients, as are uſed in the proceſs of the Pruſſian Blue, conſtantly produces that Colour.

1) Henckel diſcovered that a Lixivium from the Aſhes of the Kali, upon the addition of an Acid, yields a *Blue* ſimilar to the Pruſſian Blue: but I believe no cauſe has hitherto been aſſigned, why that Plant affords a *Blue*, preferably to the other

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(19) Juncker, Conſpect. Chem. Vol. i. p. 573. Major adhuc cernitur differentia in confuſione ſolutionis ferri per aquam fortem factæ et *ſalis alcali fixi*, quippe ſolutio illa ferri ſi in ſaturum lixivium alcali copioſum immittatur, utraque ſine præcipitatione copulantur. Ib. 230 — namque eodem momento, quo ferrum ab acido decidit, ab alcali combibitur.

other Vegetables in the *Aſhes* of which *Iron* is equally to be found.

I ſhall therefore endeavour to point out the Specific Difference upon which this depends.

That the Kali contains an *Animal Phlogiſton*, I apprehend, will appear from theſe circumſtances: a Volatile Salt, and an Oil exactly reſembling an *Animal* one, are obtainable from it; the plant when putrefied yields a ſmell not diſtinguiſhable from that of putrefied *Animal* Subſtances, and in that ſtate it is reſorted to by Flies, and Worms are bred in it; when expoſed to a naked fire, it's ſmell reſembles that of burned Feathers or other parts of *Animals*. (20)

This Animal Subſtance ſeems to have been received by the Plant, during it's growth, from the Sea-Water, which appears to be impregnated with an Unctuous matter, ariſing probably from the Animals which inhabit it: by this Unctuous or Saponaceous quality the Froth, which ariſes from the Agitation of the Waves in tempeſtuous weather, is cauſed.

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(20) Flora Saturniſans Supplem. Cap. 2. Henckel who has in this Chapter given the account of the Kali, which I have here related, attributes the Blue procurable from this Plant to the reſult of an Acid united to the earth of any plant which is impregnated with Sea-Salt. "Je crois pouvoir conclure qu'il "eſt poſſible de faire une *Couleur bleue* avec la *terre* d'une plante "impregnée de *Sel Marin*, et un Acide quelconque." He does not ſuſpect that *Iron* was concerned in the production of that Colour: nor has it been hitherto obſerved by any Writer that I have met with that the *Marine Plants* are really poſſeſſed of an *Animal Principle*.

Thus the property in the Kali of yielding a Blue Precipitate ſeems to depend upon this difference of it's Inflammable Principle from that of other Plants. For the Kali is *naturally* ſtored with an *Animal Phlogiſton*, which enables it's Alcaline Lixivium powerfully to diſſolve the Iron contained in it's Aſhes. The Fixed Alcaline Salts of other Plants acquire the ſame Solvent Power by the *Artificial* Addition of an *Animal Phlogiſton*, viz. that which is contained in Blood or other parts of Animals Calcined with thoſe Alcalies.

2) Another remarkable inſtance of the *Solution of Iron* by a Fixed Alcali appears in the Deflagration of that Metal with Nitre, for by that means the *Iron* unites with the *Alcaline* Baſe of the Nitre, and with it becomes ſoluble in Water: the Solution is tinged of a *Purpliſh Blue*. (21)

This Colour appears to me to be evidently cauſed by the ſame Ingredients, which produced it in the Pruſſian Blue. For it is well known that Nitre is poſſeſſed of an *Inflammable Matter*, and I apprehend that it imparts a portion of that Principle, together with it's Alcali, to the Iron, during it's Detonation with it.

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(21) Juncker, Conſpect. Chem. Vol. i. p. 934.
Ferrum cum nitro accenditur experimento Croci Zwelferi, ubi ſi equales partes limati ferri et Nitri in tigillum candens immittatur, et facta fulguratione, maſſa cito exemta elutrietur aqua affuſa, hæc ſaturate *Violaceo*, non rubro ut vulgo ſcribunt, Colore tingitur.

It is probable that the *Phlogiſton* of Nitre is of the *Animal* kind, as it owes it's Origin chiefly to ſuch Animal matters as yield an Oily Urinous Salt. (22)

Kunckel obtained from Blood, (the Subſtance uſed to impart it's Phlogiſton to the Alcali in the preparation of Pruſſian Blue) a twentieth part in weight of Nitre. (23)

I do not ſee any reaſon to diſbelieve that a portion of the Nitrous Acid is, during the Detonation, united with the Iron, as well as the Alcali: when it is conſidered how great an *Affinity* there is between that *Acid* and *Iron*.

This Detonation therefore may be conſidered as an Operation ſimilar to the Calcination, by which the Lixivium uſed in the Proceſs of the Pruſſian Blue is prepared: For in both a *Fixed Alcali* and an *Animal Oil* are united by the force of Fire.

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(22) Neumann's Chym. by Lewis; p. 198.

All Animal and Vegetable Subſtances contribute to the production of Nitre, in ſo far as they are ſuſceptible of putrefaction. Animal Subſtances, as being moſt diſpoſed to putrefy, are for this uſe the moſt proper; and the ſoft and fluid parts more ſo than the ſolid and the hard.—The following compoſitions are proper—Lime, Salt, raſped Horns and Hoofs, cuttings of Leather, and other refuſe *Animal* Subſtances, human Urine, &c.

(23) Juncker, Conſpect. Chem. Vol. ii. p. 325.

Kunckelius ex *Sanguine auimalium* Nitrum ſequente modo paravit. Sanguinem recentem in locum calidum ad putreſcendum tam diu repoſuit, donec in terram converſus eſſet: Hanc terram poſtea elixando, lixiviumque ad cuticulam uſque evaporando, et demum cryſtallizationi exponendo tractavit, atque hac ratione genuinum Nitrum obtinuit; ea quidem quantitate ut centum libræ ſanguinis quinque et plures libras Nitri ſuppeditaſſent.

The other ingredients uſed in this Experiment, viz. Iron, and a Mineral Acid, as well as the Fixed Alcali, and Animal Phlogiſton, are ſimilar to thoſe employed in the preparation of Pruſſian Blue, and the Colour, reſulting from the mixture in the preſent caſe, is nearly the ſame.

The mixture of *Purple* with the *Blue*, which takes place more in this preparation than in the Pruſſian Blue, will be explained preſently.

I have, in the note, given the Proceſs as I find it related by chymical writers, the Remarks and Explanation of it are ſuch as have occurred to me.

3) I had many years ſince obſerved that *Galls*, infuſed in diſtilled Water only, were ready *Solvents* of *Iron:* and by a *Solution* of that Metal in an Infuſion of Galls, I not only prepared an extremely Black and durable Ink, but by it's means, without the addition of any Acid, I dyed Silk and Woollen Cloth of a good and laſting Black.

I was ſatisfied from many Experiments which I have made on thoſe Aſtringents, that they contain an *Inflammable matter* which, from the means of their formation as well as from other reaſons, appear to be principally of the *Animal* kind. One remarkable effect ariſing from this Phlogiſton in Galls, is the ready and violent Effervеſcence which takes place when they are diſſolved in the Nitrous Acid: For, upon mixing Galls with Aqua Fortis, I found that they were diſſolved with an ebullition, heat, and rapid emiſſion of Fumes, equal to thoſe which accompany the Solution of Iron in the ſame Acid.

I ſhall in a future paper ſhew that Galls, even in their intire ſtate, before they have been burned, contain a large quantity of Fixed Alcaline Salt.

Several other curious Circumſtances attended the examination of Galls, but as they do not relate to this Subject, I ſhall reſerve an account of them to another occaſion.

After having obſerved that an *Animal Phlogiſton* and the Power of *Diſſolving Iron* were United in the Infuſion of *Galls*, as well as in the *Lixivium* uſed in the Proceſs of *Pruſſian Blue*; it readily occurred to me that the mixture of *either* of theſe Liquors, with a Solution of Vitriol, produces the effect of Changing it's Colour from *Green* to *Blue*, by one and the ſame cauſe, viz. by *farther diſſolving* the *Iron* contained in the Vitriol.

The *production* of Black, Blue, and Purple in Vitriolic and Chalybeate Waters, from the application of Galls and other aſtringent Vegetables, has been conſtantly obſerved, but I believe the *Cauſe* of thoſe Colours and of the difference of them has not hitherto been aſſigned. I ſhall, in order to explain theſe appearances, relate ſome Experiments and Obſervations which I have made on this Subject.

Iron ſeems to be in the moſt perfect State of Solution in the Chalybeate Waters: Their Tranſparency, their Want of Colour, and their Medical

Efficacy, ariſe from the *Iron* contained in them, being divided into extremely *minute* particles.

This minute diviſion of the Iron is undoubtedly cauſed by the Ingredients which are added to the Vitriol in thoſe Waters. Theſe ingredients, as appears from the accurate experiments of Seip, are principally an Alcaline Salt, and a calcareous earth.

Having learned from hence, that the Iron ſo minutely divided in theſe Waters is united to an *Alcali*, as well as to the *Vitriolic Acid*; in order to produce the like effects by artificial means, (as far as relates to the ſubject of this paper) I made the following Fxperiments.

To four ounces of a Solution of Pot-Aſh, I added half a Drachm of a ſaturated Solution of *Green Vitriol*; after this mixture had ſtood ſome time, a great part of the Iron was precipitated. I then decanted the clear Liquor and filtered it.

To an ounce of this liquor I added one ſmall drop of an infuſion of Galls, which inſtantly produced in it a beautiful *blood Red*, without the leaſt admixture of *blue*.

To an ounce of a ſaturated ſolution of *Green Vitriol* I added one drop of an infuſion of Galls, which produced in it a *Blue* without the leaſt admixture of *Red*.

From theſe Experiments it appears, 1) that the Iron contained in Vitriol is capable of *being farther diſſolved* in a *Fixed Alcaline* ſubſtance, for a ſmall quantity of that Metal, is in this experiment *Diſ-*

ſolved and permanently diffuſed throughout a large quantity of the Solution of Pot-Aſh.

2) *Green Vitriol*, which with Galls afforded a Blue Colour, when *farther diſſolved* in an *Alcali*, is found to *Aſcend* from Blue to *Red*, by means of that *Attenuation*.

3) It appears, from theſe Experiments, that the different degrees of *Purple* and *Blue*, which have been obſerved in Chalybeate Waters, may be eaſily accounted for, from the *Greater* or *Leſs* prevalence of the *Acid* or *Alcaline* Ingredients in thoſe Waters.

4) As an Infuſion of *Galls* has been already ſhewn to poſſeſs a power of *Diſſolving Iron*, the *Blue* Colour into which *Green* Vitriol is changed by the addition of thoſe aſtringents, ſeems to ariſe from the Iron in the Vitriol being *farther Attenuated* by the *Galls*; it's Colour *Aſcending* accordingly from *Green* to *Blue*, the Colour next *above*.

In the ſame manner, when to a Chalybeate Water, which with a Small quantity of Galls produces a *Blue* or bluiſh Purple, a Larger portion of Galls is added, the Colour *Aſcends* from *Blue* to *Red*, by means of their *Solvent* quality.

Thus it appears that *Green* Vitriol, by the addition of Galls which per ſe poſſeſs a power of *Diſſolving Iron*, *Aſcends* from *Green* to *Blue*; and that the ſame by a *farther Attenuation* in a *fixed Alcali*, or by a *larger* quantity of *Galls*, *Aſcends* farther from Blue to *Red* being ſtill farther *Divided*. And

5) It appears that in the production of *Blue* or *Purple* by the union of *Galls* and *Vitriol*, ſimilar

Principles are employed, as in the production of thoſe Colours in Pruſſian Blue, the Blue from the Aſhes of Kali, and from Iron deflagrated with Nitre: For I have ſhewn that the Ingredients in each of theſe proceſſes, are *Iron*, a *Fixed Alcali*, a *Mineral Acid*, and an *Animal Phlogiſton*.

It muſt here be obſerved that in all theſe proceſſes the *Phlogiſton*, beſides it's Solvent power, produces another effect on the Iron: For by uniting with the Metallic particles, it greatly Increaſes their Reflective and Refractive power, and thereby enables the ſolution of Vitriol, &c. (which, according to it's degree of dilution, is either Colourleſs or faintly Coloured) to exhibit an extremely *Vivid* Colour.

The *Change* of the Colour of *Green* Vitriol therefore from *Green* to *Blue* and *Purple* is cauſed by the *Solvent* quality of the *Galls*, &c. and the *Vividneſs* of the Colour is occaſioned by the addition of the *Inflammable* matter to the ferruginous particles, whereby their Reflective and Refractive power is greatly increaſed, according to the Doctrine of Sir Iſaac Newton, who has ſhewn that the Reflective and Refractive powers of Inflammable bodies are much greater than thoſe of other Subſtances.

This Obſervation of the Increaſe of *Vividneſs* when *Inflammable* Subſtances are uſed, ſuggeſted to me the thought of Diſſolving *Green* Vitriol in Spirit of Wine, and I accordingly found that the

Blue Colour produced from that Solution, by the Addition of Galls, was extremely beautiful and Vivid, greatly exceeding that which aroſe from the Solution of the ſame Vitriol in Water.

The other circumſtances of theſe proceſſes, relative to *Blue* Subſtances produced from *Iron*, may be alſo illuſtrated by the conſideration of the qualities of the Ingredients which enter into their compoſition.

It is well known that Inflammable Subſtances are miſcible with Fixed Alcaline Salts, and with them form a ſaponaceous compound.

The readineſs with which the *Animal Phlogiſton* is united *to Iron*, appears from the converſion of that Metal into Steel, for in that operation, the Iron imbibes from Horn, Leather, or other *Animal* Subſtances, ſo much Phlogiſton, that it becomes ſaturated with it: and the Calx of Iron, like that of all other imperfect Metals, readily unites with Fat Subſtances in general.

It is not therefore to be wondered at that the *Inflammable Principle*, which appears to have ſo great an *Affinity* with *Iron* ſhould by it's Union with Fixed Alcaline Salts, communicate to them a greater Solvent power relative to that Metal.

From theſe Experiments and Obſervations it appears that *Green* Vitriol, in proportion as it is Deprived of it's Solvent part, is changed to *Yellow*, *Orange*, *Red*, and *Purple*: and by a contrary proceſs, viz. by a farther Attenuation by means of the Phlogiſticated Lixivium, in the Proceſs of Pruſſian Blue, &c. the Colour of the Iron *Aſcends* from Green to *Blue*.

Iron attenuated by Alcali and Phlogiſton - - - - - - - - -	Blue.
Vitriol of Iron - - - - - - -	Green.
Vitriol of Iron in proportion as its Solvent part is expelled - - - -	Yellow. Orange. Red. Purple.

Thus *all* the primary Colours are produced from the ſame Metal, in proportion as it's particles are *Attenuated* or *Incraſſated*.

Changes of Colour in Iron united to Glaſs.

IRON is not only Soluble by the means hitherto mentioned, but it may be Diſſolved alſo by mixing it with other Subſtances which are capable of being intimately united with it.

Glaſs is one of the moſt convenient Subſtances for this purpoſe: For according to the Quantity of Glaſs uſed in diſſolving the Iron, and the degree of Heat employed in effecting the Solution, all the primary Colours are produced.

Red.

Thus when a *large* quantity of calx of Iron is united with a *ſmall* proportion of Glaſs, and a moderate heat is applied, the *Red* (24) Enamel Colour is produced: the *Red* generally uſed on the Porcelain of China is ſaid to be of this kind. A *Red* Glazing for earthen ware is alſo made from theſe ingredients. (25)

Yellow.

If a Leſs proportion of Iron be mixed with Glaſs it imparts to it a Yellow Colour: by this means Topazes are imitated, and I have produced ſeveral ſorts of *Yellow* by diſſolving a proper quantity of Iron in a tranſparent Colourleſs Glaſs.

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(24) Felibien, *Princ. de l'Archi.* — *Lib.* 3. *Cap.* 10. — *de l'email* 310. " Le *Rouge* qui repreſente a peu prés le Vermilion, " eſt fait avec du *Vitriol, qu'on calcine* entre deux creuſets luttez. " Il ne lui faut qu'un *feu mediocre* d'environ une heure."

Art *de la verrerie, de Neri, Paris*, 1752. p. 70.

Le crocus martis ou ſaffran de Mars n'eſt autre choſe qu'une bonne calcination du fer, au moyen de laquelle il donne une couleur très *Rouge* au *Verre.*

(25) Kunckel, Art de la verrerie, Lib. 2. § 53.

Autre couverte Rouge encore plus belle; Prenez des morceaux de verre blanc; reduiſez les en une poudre impalpable; prenez enſuite du *Vitriol Calciné juſqu'a devenir Rouge*, ou plutot du caput mortuum qui reſte après la diſtillation de l'huile de vitriol, édulcorez le avec de l'eau chaude pour enlever les ſels; prenez de ce caput mortuum autant que vous jugerez en avoir beſoin, et mêlez le avec le verre broyé; vous aurez par ce moyen un très beau *Rouge* dont vous pourrez vous ſervir à peindre, vous ferez enſuite recuire votre ouvrage.

Iron is alſo frequently uſed in *Yellow* Glazings for earthen ware. (26)

Green.

I expoſed to a great degree of heat, and for a conſiderable Time, a piece of *Yellow* Glaſs, which had received its tinge from *Iron* alone; by this means the *Yellow* was changed into *Green.*

I have, in a former paper, (27) ſhewn that the *Green*, with which the Glaſs uſed for bottles is tinged, is occaſioned by the *Iron* contained in the Vegetable Aſhes and Sand, of which that Glaſs is compoſed. The Quantity of Iron contained in theſe materials, is much leſs than that which enters into the Compoſition of the *Yellow*, and *Red* Glaſs: the Vegetable Aſhes contain a very ſmall proportion of Iron: From the Sand I ſeparated, by a magnet, grains of Iron ore weighing about one twentieth part of the Sand; and it is probable that thoſe grains do not conſiſt intirely of Iron, but are mixed with a ſtony matter.

Blue.

When the pots in which this *Green Glaſs* has been kept in fuſion are nearly emptied, the Glaſs remaining

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(26) Kunckel, Art de la Verrerie, Part 2. § 30. Couverte d'une beau *Jaune.*

Prenez ſeize parties de Cailloux, de *Limaille de Fer* une partie de litharge 24 parties, faite fondre ce melange.

Ib. § 35. Prenez de Cendres de plomb et de Cailloux blancs douze parties, de Limaille de Fer une partie, faites fondre a deux repriſes.

(27) Philoſo. Tranſ. Ann. 1765.

Iron moſt Diſſolved by Glaſs - -	Blue.
Iron, in proportion as it is Leſs Diſſolved by Glaſs, - - - - - - -	Green. Yellow. Red.

Colours of Iron Diſſolved in different Menſtrua.

FROM Iron, diſſolved in its ſeveral Menſtrua, Colours are produced in proportion as the Solvent Power of thoſe Menſtrua is greater or leſs.

Thus, with the Vitriolic Acid which has the greateſt Solvent power relative to (34) that Metal, it gives a *Green* Colour. (35)

With the *Nitrous* (36) and *Marine* (37) Acids, whoſe ſolvent power is weaker than that of the Vitriolic, it gives a *Yellow* or *Orange* Colour.

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(34) Juncker, Conſpect. Chem, Vol i. p. 207. — Ferri Exiguam portionem imbibit *Aqua Fortis*, adhuc *Minorem* ſpiritus *Salis*, *Plurimam* acidum *Vitrioli*, *Minimam Acetum*.

(35) Ib. Vol. i. p. 209. — Acidum *Vitrioli* cum Ferro *Gramineum* colorem repræſentat.

Ib. Vol. i. p. 936. — Ferrum ſolvitur ab acido Sulphuris ſeu *Vitrioli* in *Graminei* coloris ſolutionem, quæ in cryſtallos Vitrioli Martis artificialis concreſcit.

(36) Ib. Vol. i. p. 209. — Acidum *Nitri* cum *Ferro* Flavorubellum colorem ſiſtit.

(37) Ib. Vol. 2. p. 331. — Spiritus *Salis* cum *Ferra* parum tingitur, et colorem vix *Flavum* exhibet.

When diſſolved in the *Vegetable* Acid of *Tartar* (38,) or Vinegar (39,) whoſe ſolvent power is ſtill weaker than that of the Mineral Acids, a *Red* Colour is conſtantly produced.

A ſimilar Red is alſo produced by a ſolution of Iron in Aqua Fortis, when it's Solvent power is Weakened by the addition of Neutral Salts (40,) of Alcaline Salts (41,) or of the Weaker Vegetable Acids (42).

It appears, from the 38th and 40th notes, that the medical qualities of *Iron* may be, in ſome meaſure, diſtinguiſhed by it's Colour. For the *Red* preparations of that Metal, being united to to the Weakeſt Solvents, are much milder than

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(38) Ib. Vol. i. p. 937.—*Ferrum* ſolvitur ab *Aceto* deſtillato, quocum cryſtallos *Dulces* largitur, itemque a *Tartaro* in *Subrubicundam* tincturam.

(39) Ib. Vol. i. p. 374.—*Ferrum*—quocum *Acetum* conſtantiorem *Rubedinem* ſubit.

(40) Ib. Vol. ii. p. 249.—Ex *Marte* Cryſtalli *Rubentes*, *uſui Interno* ſatis *Commodæ* per Aquam Fortem, pauxillo Nitri alteratam adquiri poſſunt.

Ib. Vol. i. p. 367.—Extractio Ferri per Acetum, Sal ammoniacum et Aquam Fortem.

—— Si ſub initium nec ulla agitatio, neque externus Calor acceſſerit, tincturam Coloris prorſus Sanguinei habebis.

N. B. By avoiding Heat or Agitation, the power of this Solvent is ſtill farther weakened.

(41) Ib. Vol. i. p. 217.

(42) Ib. Vol. ii. p. 254.—Vitriolum cum Aceto deſtillato digeſtum, Viridem in Rubrum Colorem mutat.

Ib. Vol. i. p. 375. Crocus Martis tenerrimus qui per Aquam Fortem e Ferro ſeparatur, uti per aquam regis ſolvitur aurea flavedine; ita ſimulatque huic ſolutioni Acetum deſtillatum adjungitur, pulcherrima Rubedo exiſtit.

thoſe which contain Iron more minutely Diſſolved by the Stronger Acids.

Iron diſſolved in it's Strongeſt Acid Solvent, the Vitriolic Acid, - -	Green.
In it's Weaker Acid Solvents, the Marine and Nitrous Acids, - - -	Yellow. Orange.
In it's Weakeſt Acid Solvents, the Vegetable Acids, - - - - - - -	Red.

Colour of Calces of Iron Precipitated from it's Solutions.

WHEN the Iron, diſſolved in the Vitriolic Acid, is Precipitated from that Solution, it's parts, by *Coaleſcing* into Larger maſſes, *Deſcend* in Colour from Green to *Yellow*, and are depoſed in form of an Ochre. (43)

The *Yellow* Solution of Iron in the Nitrous Acid, in the ſame Manner, lets fall a *Red* Sediment, when ſuperſaturated (44,) and this is more effectually brought about when the Iron is rapidly diſſolved (45;) for in that caſe the Solution becomes the more Saturated, and the Iron is precipitated from it in a denſer ſtate. Accordingly, as in the *Green* Solution by the Vitriolic Acid, the Colour of the Precipitate Deſcended to *Yellow*; in this *Yellow* Solution the Colour of the Precipitate Deſcends to *Red*.

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(43) Ib. Vol. ii. p. 249. — Purificatur Vitriolum ſolvendo in aqua pluvia, aut quacumque deſtillata. — Hac ratione ſenſim demittit ſedimentum, *Ochram* Colore æmulans.

(44) Ib. Vol. i. p. 211. Hoc modo Aqua Fortis magnam adhuc quantitatem *Ferri* corrodet et in *crocum Rubrum* convertet.

(45) Ib. Vol. i. p. 214. — Si limatum ferrum uſque ad triginta grana per vices ingeratur, tum decidens crocus ex *Rubro Flaveſcit*; ſi vero *per uncias* injectio fiat, idem *Rubicundum* magis Colorem repræſentabit.

The Sediment from Iron diſſolved in the Marine Acid is black, probably from retaining it's Metallic State, it being a known property of the Marine Acid, that it does not effectually deprive Iron diſſolved in it of it's Phlogiſton. (46) The ſediment in this State reſembles the Metals reduced to Blackneſs by rubbing them upon other Subſtances, to draw black lines, or by being ground ſmaller. But when part of the Colouring particles have thus ſubſided from the ſolution, the Liquor becomes by that means *Rarer*, and it's Colour Aſcends from *Yellow* to *Green*. (47)

Colour of Calces of Iron Diſſolved.

AS this proceſs is contrary to that of Precipitation, ſo the changes of the Colours ariſing from it, proceed in a contrary Order, *Aſcending* by means of the *Solution* of theſe Calces.

Thus

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(46) Dict. de Chym. par M. Macquer.
Fer — L'acide Marin diſſout auſſi le fer avec facilité, et meme avec activité; mais il ne lui enleve point ſon principe inflammable auſſi efficacement que l'acide nitreux, et meme que le vitriolique, quiqu'il ne le laiſſe point ſans altération à cet egard.

(47) Ib. Vol. i. p. 209. — Acidum Salis communis cum Ferro primum aliquantum *Flaveſcit*, dein *Glandeſcit Subſidente* ſenſim nigro *Sedimento*.

Green.

Green Vitriol of Iron is often found native, and is ſimilar in its other qualities, as well as in it's Colour, to the Artificial *Vitriol of Iron.*

Blue.

A *Blue* Earth is frequently found in Peat Moſſes, an account of this Subſtance was read at the Royal Society, Feb. 13, 1766, and it appears from that paper that *Iron* is the metal with which this *Blue* Earth is impregnated.

It ſeems to me probable that the *Iron* contained in this Subſtance was diſſeminated through the Vegetables whilſt growing, of which the Peat is well known to be compoſed, and this may be the cauſe of it's Particles being ſo minutely *Divided* as to produce a *Blue* Colour.

I have produced a *Blue* very ſimilar to this by expoſing Vegetable Aſhes to the heat of a Furnace for ſome days.

Mr. Margraf. Opuſcules Chym. Diſſ. 23, has ſhewn that the *Blue* Colour of Lapis Lazuli is owing to *Iron* contained in it.

THUS it appears that all the Changes of Colour, to which Iron is ſubject, are entirely conformable to the Law which prevails in Vegetable and Animal Subjects. (51)

Changes of Colours in Mercury.

The Experiments which have been made on Mercury, by the Chymiſts, Alchymiſts, and various Artificers, are extremely numerous: but none of them have hitherto been employed in Optical Inquiries. In my application of them to this Subject, I have cited ſuch Authors as have beſt deſcribed the Circumſtances relative to it: preferring their Authority, when it was to be met with, to a relation of my own Experiments on that Metal. Amongſt the Chymical Works, which I have referred to on this occaſion, thoſe of M. Bayen have afforded me the greateſt aſſiſtance, as will appear from the Paſſages which

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(51) A few Copies of the part of this Work preceding page 55, were printed ſome years ago, but were not publiſhed. A French Tranſlation of it, together with an Introduction written by the learned Profeſſor De Caſtillon, is inſerted in the Memoirs of the Royal Academy of Sciences and Belles Lettres of Berlin, for the Year 1774. The ſubſequent Experiments and Obſervations have ſince been added.

I have tranſcribed from his Eſſays on the Nature of Mercurial Precipitates. (52)

The Preparations here conſidered, are arranged according to their ſeveral Solvents; and the colours of each of them are conformable to the Rule, which obtains in all the inſtances already given.

Colours of Mercury diſſolved in the Nitrous Acid.

From Mercury, diſſolved in the Nitrous Acid, a white Salt is obtained, which is called Mercurial Nitre. In proportion as the Solvent is extricated from it, the Maſs becomes *Yellow*, then *Orange*, and laſtly *Red*.

(1.) The expulſion of the Acid, and the conſequent Changes of Colour, are readily effected by expoſing the Mercurial Nitre to a gradual heat, by which means the Acid riſes in Vapours, and its Evaporation is accompanied by thoſe Alterations of Colour in the Maſs. (53)

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(52) Eſſais Chymiques, ou Expériences faites ſur quelques précipités de Mercure, dans la vue de découvrir leur nature. Par. M. Bayen.—Journal par M. l'Abbé Rozier. Paris.

(53) Macquer. Dict. Chym. Art. Red Precipitate. " If a ſolution of Mercury, in nitrous Acid, be reduced to dryneſs by Evaporation,

The Red Matter, which finally reſults from this Operation, is improperly called a Precipitate: as it is a Calx of Mercury, from which the greateſt part of the Acid Menſtruum has been expelled by heat, in the ſame manner as when Colcothar is obtained from Vitriol of Iron.

(2.) When the tranſparent colourleſs Solution of Mercury in the Nitrous Acid is applied to various ſolid matters, as Bones, the Skin, &c. the Acid is abſorbed by theſe Subſtances, and the Mercury, thus deprived of its Solvent, aſſumes a Purple Colour.

(3.) Although the Nitrous Acid is moſt readily and effectually expelled from the Mercurial Salt by

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ration, and the mercurial Nitre thence formed be put into an open matraſs ſet in a ſand-bath, with a fire gradually increaſing, the nitrous Acid will diſengage itſelf from the Mercury, and evaporate in a red vapor. *While the Acid evaporates*, the ſaline Mercurial maſs loſes its original whiteneſs, becomes *Yellow*, then *Orange*, and laſtly *Red*."

The Work from which this paſſage is quoted, although arranged in the form of a Dictionary, is one of the beſt general Treatiſes on the ſubject, and is written by an excellent Chymiſt: for which reaſon I have not ſcrupled to cite it where the Proceſſes, to which I refer, are more fully deſcribed than in other chymical works.

heat, yet there are other methods by which a conſiderable quantity of it may be extricated.

When a ſaturated Solution of Mercury in this Acid is diluted by a large Quantity of Water, part of the Solvent is ſeparated, and a Yellow Precipitate is immediately formed from this Decompoſition of the Saline matter. M. Monnet, in a Treatiſe which abounds in new and uſeful remarks, calls this Yellow Precipitate Nitrous Turbith. (54) The ſame effect is alſo produced by a proper application of Water to Mercurial Nitre. (55)

In order to preſerve the Colour of the Maſs thus procured, it is neceſſary to guard it from the Light of the Sun: for I have often obſerved that, when this Preparation is expoſed in a clear glaſs veſſel, even though it be cloſed and filled with water, the ſide which is neareſt the window becomes black, whilſt the oppoſite ſide continues Yellow. (56)

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(54) Traité de la Diſſolution des Metaux, par M. Monnet. Amſterdam, 1775, c. 13, § 2.

(55) Ib.

(56) This effect appears to be produced by the communication of Phlogiſton from the Matter of the Sun's Light: For, whenever any metallic ſubſtances are poſſeſſed of much inflammable matter, whilſt they

(4.) When Mercury, thus diſſolved, is deprived of its Menſtruum by various Earths, or Alcalies, its Precipitates aſſume a Green, Yellow, Orange, or Red Colour, according as more or leſs of the Acid is ſeparated from the Metal by their means.

Thus Lime, whoſe Affinity to the Acid is leſs than that of Alcalies, gives a *Green* or Olive coloured

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they are reduced into minute particles, they become *Black*. As when Calces, from the Solutions of *white* Metals, are expoſed to the Vapours of Hepar Sulphuris, or are precipitated by it: When Mercury is precipitated from its Solution by volatile Alcali, on account of the inflammable matter which it is known to contain; when Æthiops Mineral is formed by a large proportion of Sulphur with Mercury; or when that Metal, or others, are mechanically reduced into a fine powder, ſtill retaining their original quantity of Phlogiſton.

In the ſame manner the Solar Light communicates Blackneſs to the white Precipitate of Biſmuth, to Mercurius Dulcis, to the Acetous Mercurial Salt, and to a Solution of Silver from which the acid has been abſorbed by chalk.

I have placed theſe Remarks ſeparate, becauſe although they relate to the colour of Mercurial Preparations; yet as the change, which is here obſerved, does not ariſe from a greater or leſs degree of Solution, it does not immediately fall under the main ſubject of our conſideration.

ed Precipitate. (57) It is not neceſſary to enumerate the ſeveral Precipitants of an intermediate Strength, by which the intermediate Colours are produced: I ſhall only obſerve that a Solution of fixed Alcali, from its great Affinity with the Menſtruum, abſorbs ſo much of it, that the Precipitate formed by its aid becomes *Red*. But, in order to give the utmoſt Brightneſs to the Colour of this Preparation, it is neceſſary further to extricate by Heat the portion of Acid, which remains united with it: for, after this Operation, its Red Colour becomes equal in Luſtre to that of Vermilion. (58)

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(57) Exp. par M. Bayen. Février, 1774, p. 131——138. J'ai fait diſſoudre quatre onces de Mercure crud dans une ſuffiſante quantité d'eſprit de nitre pur——J'ai verſé ſur huit pintes d'Eau de Chaux récente, une ſuffiſante quantité de diſſolution mercurielle, et j'ai obtenu un précipité de couleur *Olive* foncée.

(58) Ib. p. 131—133. J'ai verſé deſſus peu-à-peu une quantité ſuffiſante de liqueur de ſel de tartre fort étendue d'eau diſtillée; il s'eſt fait un coagulum *Rouge*, qui bientôt a gagné le fond du vaſe.—Par des lavages multipliés, tant à chaud qu' à froid, j'ai édulcoré, autant que j'ai pu, le Mercure qui étoit ſous la forme d'une poudre *Rouge*.

J'ai mis quatres gros du meme Précipité dans un bocal de verre, haut et étroit, que j'ai placé dans un bain de ſable qui pouvoit recevoir un aſſez grand degré de chaleur. La matiere, en s'échauffant peu-à-peu, exhala bientot des vapeurs acido-nitreuſes——La matiere employée à cette opération avoit perdu quinze grains, ſoit en acide, ſoit en mercure revivifié; et de couleur de brique obſcure qu'elle étoit avant ſa calcination, elle étoit devenue d'un *Rouge vif*.

(5.) The ſame Precipitate, when expoſed to a conſiderable heat in a glaſs retort, is ſublimed, and forms layers regularly arranged in the neck of the Veſſel, of the following Colours, viz. *White*, *Yellow*, *Orange*, *Red*; each of theſe correſponding with the quantity of Acid which they retain. I have here cited a part of the Experiment relative to this Subject, becauſe not only the Circumſtances of the Changes of Colour, but thoſe alſo of the Extrication of the Acid, are detailed in it. And I hope that it will be ſatisfactory to its ingenious Author, to find that his Obſervations are conformable to regular Laws of Optics, as well as to thoſe of Chymiſtry. "Le bec de la retorte " exhaloit une forte odeur d'acide nitreux, et on " voyoit à ſon orifice une couche mince d'une ma- " tiere *blanche* qui ſe prolongeant d'environ deux " pouees, ſe perdoit dans une autre couche *jaune*; " celle-ci devenoit *plus foncée*, et finiſſoit en s'épaiſ- " ſiſſant, par être d'un beau *rouge de rubis*.

" Je détachai le plus que je pus de la portion " blanche; elle étoit ſoluble dans l'eau à laquelle " elle communiqua toutes les propriétés de la diſſo- " lution mercurielle ordinaire; j'en mis un peu ſur " le feu, *l'acide* nitreux *s'exhala*, et cette matiere " blanche devint *rouge*. C'étoit enfin du vrai *nitre* " *mercuriel* qui avoit non ſeulement la portion d'acide

" propre au précipité, mais encore une portion de " celui que nous ſavons s'être exhalé pendant l'opé- " ration. La couche *jaune-orangée* etoit auſſi du " nitre mercuriel qui avoit *moins d'acide* que la pré- " cedente; celle qui étoit *couleur de ſafran* en con- " tenoit *encore moins*; enfin celle qui étoit *couleur de* " *rubis*, en avoit le *moins poſſible*. C'étoit un pré- " cipité ſemblable en tous points à celui qui eſt " connu dans les pharmacies, ſous la dénomination " de précipité rouge: on ſcait que dans la prépara- " tion de ce dernier, le nitre mercuriel, *en perdant* " *peu-à-peu ſon acide*, paſſe par toutes les nuances " qui ſont entre le *jaune-foible* et le *rouge-eclàtant*. " Voilà exactement ce qui eſt arrivé dans mon opéra " tion." (58)

Colours of Mercury diſſolved in the Marine Acid.

By the Union of Mercury with a large quantity of the Marine Acid, Corroſive Sublimate is formed. The Colour of this White Salt is not capable of being changed to Yellow or Red, by a mere expoſure to Fire; for it is intirely ſublimed by heat, in its original Form and Colour, on account of the Volatility which Mercury, as well as other metallic ſubſtances, acquires from Marine Acid.

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(58) Exp. par M. Bayen, Avril, 1774, p. 292.

Nor is it ſubject to a loſs of its ſolvent, ſo as to aſſume a Yellow Colour, by the addition of Water, as it is intirely ſoluble therein. Its incapacity of being thus decompoſed ariſes from the great proportion of Acid united to the Mercury, and from the firmneſs of their Union. In order, therefore, to produce this Decompoſition, and the Colours which accompany it, it is neceſſary to uſe ſuch intermediate ſubſtances as are capable of abſorbing the Acid, by their Affinity with it.

Accordingly, thoſe ſubſtances, which have the greateſt affinity with the Acid of the Corroſive ſublimate, diſengage from its Solution a Red Precipitate: and thoſe, whoſe affinity with it is leſs, produce a Yellow one.

Thus Oil of Tartar ſeparates from this Solution a *Red* Precipitate (60), which, as Lemery rightly obſerves, is, of all the Mercurial Preparations, moſt properly ſo called. Lime-Water, which has a leſs

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(60) Lemery's Courſe of Chym. chap. 8. Mercury. Mix four or five ounces of Sublimate Corroſive powdered, in a glaſs or marble mortar, with eight or nine ounces of warm water, ſtir them about for half an hour, then let the liquor ſettle, and pour it off by inclination, filter it and divide it into three parts to be put into ſo many Vails.

Affinity with the Acid, when added to the ſame ſolution, diſengages from it a *Yellow* Precipitate. (61)

But the Colours of theſe Precipitates are liable to ſome Variation, according to the greater or leſs quantity of Acid in the Solution: for when the Acid abounds in the ſaline liquor, the Alcaline Precipitate inclines to *Yellow*; and when there is a deficiency of Acid, the calcareous Precipitate inclines to *Red*.

The ſame difference of Colour takes place, when a fixed Alcaline Liquor, inſtead of being mixed with a Solution of Corroſive Sublimate, is added to that Salt undiſſolved: for in that caſe the Alcali is not capable of being applied to the Maſs ſo perfectly, on which account leſs of the Menſtruum is diſengaged, and

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Pour into one of theſe Vials ſome drops of the Oil of Tartar made per Deliquium, there falls immediately a Red Precipitate.——It is the *trueſt Red Precipitate* of any.

(61) Ib. Pour into the laſt of theſe Vials five or ſix ounces of Lime-Water, you have a *Yellow* water, that is called Phagedenic water.——If you let the Liquor ſettle, it will let fall a *Yellow* Precipitate.

and thus the White Colour is not changed to *Red*, but to *Yellow*. (62)

The Precipitate obtained from this Salt by a fixed Alcali, when carefully waſhed, and expoſed to a ſufficient heat, affords a conſiderable portion of *bright Red Calx*, not inferior in luſtre to the others of that Colour, which are produced from Mercury by Fire. (63)

Volatile Alcali, dropped ino a Solution of Corroſive Sublimate, does not extricate from the Saline mixture a ſufficient quantity of Acid, to change its Colour: But abſorbing leſs of the Menſtruum, leaves the

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(62) Lemery's Courſe of Chym. chap. 8. Mercury. The liquor of Salt of Tartar turns Sublimate *Red*, when it is diſſolved in common water alone: and it makes it *Yellow*, when the Sublimate is not diſſolved.

(63) Exp. par M. Bayen, Fevrier, 1775, p. 151. Expériences faites ſur le Précipité de la diſſolution du Mercure ſublimé corroſif par l'Alkali fixe.

Le Précipité obtenu de huit onces de Sublimé Corroſif, peſoit, étant bien édulcoré et ſéché, cinq onces, ſix gros, vingt-deux grains; mis dans une retorte de verre et expoſé à une chaleur convenable, il s'en eſt élevé deux onces, cinq gros, trente-trois grains de Mercure doux; il eſt reſté dans la retorte, deux onces, ſept gros, quarante-un grains de chaux mercurielle d'un *Rouge éclatant*.

the Mercury united to nearly ſuch a proportion of it as forms Mercurius Dulcis, which, on account of its inſolubility, is ſeparated in form of a *White* Precipitate.

It is proper here to obſerve in general, that ſuch white Sediments are mere Cryſtals, which, from their Smallneſs, and from the interpoſition of a Medium of a different Denſity, loſe their Tranſparency. (64)

Lemery remarks that Mercurius Dulcis becomes *Yellow*, when triturated. This Colour is occaſioned by a Loſs of a portion of the Solvent, in that Operation. And, as it appears from the Works of this Chymiſt, that he ſometimes uſed Marble Mortars in theſe proceſſes; the Abſorption of the Acid may be chiefly attributed to the Calcareous Earth of thoſe Veſſels.

Colours of Mercury diſſolved in the Vitriolic Acid.

Mercury diſſolved in the Vitriolic Acid exhibits, in proportion as its Solvent is taken from it, the ſame Colours which, under ſimilar Circumſtances, are afforded by that Metal diſſolved in the other Acids.

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(64) See p. 29, above. Note.

By its Solution in Oil of Vitriol a White Salt, called Vitriol of Mercury, is formed.

(1.) When Water is poured upon the Vitriol of Mercury, the Acid is diſengaged, and the Mercury is precipitated in form of a *Yellow* powder, which is Turbith Mineral. (65)

The Colour of this preparation is deeper, and more inclining to Orange when hot Water is uſed, or when a greater quantity of it is employed: for, by either of theſe means, more of the Solvent is diſcharged: and upon examining the Water, it is found to contain the Acid which was united to the Mercury.

It appears, however, from the compariſon of this Proceſs, with the foregoing ones, that Water is not capable of intirely depriving the Vitriol of Mercury of its Solvent. And although Turbith Mineral ſhews no marks of an Acid, when ſufficiently waſhed; yet its Abſence cannot from thence be argued, becauſe ſuch an intimate union, between Acids and metallic Subſtances, is often formed, that we cannot in ſuch a Compound always expect to find evident marks of the ſeparate Ingredients.

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(65) Macquer. Dict. Chym. Art. Turbith Mineral. We ought to obſerve, that Turbith Mineral becomes *Yellow* only by being *deprived of the adhering Vitriolic Acid*, and that it remains white till it has been waſhed with a large quantity of water; in general the more perfectly it is *deprived of Acid, the deeper Yellow Colour* it acquires.

M. Bayen, indeed, has clearly eſtabliſhed the exiſtence of the Vitriolic Acid in this Preparation by ſeveral Experiments. From Turbith Mineral, which had been carefully waſhed with diſtilled Water, he obtained, by Diſtillation, a Volatile Sulphureous Acid (66). And a Mixture of the ſame ſubſtance with Sea-Salt diſſolved in diſtilled water, yielded Glauber Salt.

As the Acid cannot be intirely extricated from Turbith Mineral, by means of Water alone, it is neceſſary to employ an Alcali, in order to abſorb that portion of it which remains intimately combined with the Mercury.

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(66) Exp. par M. Bayen. Dec. 1775 p. 495. Paſſant auſſi ſous ſilence un grand nombre d'expériences tentées ſur du Turbith ſublimé juſqu' à quatre fois, je me contenterai de dire, 1°. Que ce ſel perd à chaque Sublimation une portion d'acide vitriolique, qui paſſe conſtamment ſous la forme d'acide ſulphureux.

(2.) When a Solution of Fixed Alcali is poured upon Turbith Mineral, its *Yellow* Colour is changed to a dark *Orange*. By digeſting it in a Solution of vegetable or foſſil Alcali in a ſand-heat, the Acid is more completely diſengaged from the Mercury, which, on that account, aſſumes a *Red* Colour: and the Acid is transferred to the Alcali, forming vitriolated Tartar, or Glauber Salt, according as a Vegetable or Mineral Baſis is applied in the Proceſs. (67)

(3.) Vermilion, or Artificial Cinnabar, conſiſts of a mixture of Mercury and Sulphur; from which all the Sulphur, except an eighth part, is burned off before the Maſs acquires its bright *Red* Colour; for which purpoſe repeated ſublimations are neceſſary.

If it be conſidered that of this eighth part of Sulphur, a very conſiderable part is Phlogiſton; it will appear that the Quantity of the Vitriolic Acid, which remains united to the Mercury in Cinnabar, is nearly equal to that of the Nitrous Acid retained by the *Red Precipitate.* (68)

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(67) Exp. par M. Bayen. Dec. 1775. p. 499. Si on verſe, ſur du Turbith bien lavé, une quantité d'eau diſtillée, rendue alkaline par le ſel de Soude ou de Tartre, et qu'on tienne le tout en digeſtion ſur le ſable chaud, avec la précaution d'agiter de tems en tems la matière, on ne tardera pas à voir la couleur *citrine* du Turbith, ſe changer en *rouge*, et en quelques heures, on obtiendra un vrai Précipité de Mercure.—Si on ſoumet a l'evaporation l'eau de digeſtion, on en retirera ou du tartre vitriolé, ou du ſel de Glauber, ſuivant la nature du precipitant employé.

Cinnabar of Antimony does not differ from this in its compoſition; but is thus called, becauſe its Sulphur is transferred to it from Antimony. Native Cinnabar conſiſts of the ſame ingredients, united in nearly the ſame proportion, as thoſe which form the artificial; nor does that which is made in the humid way materially differ from any of the foregoing compoſitions.

Colours of Mercury diſſolved in the Vegetable Acid.

The Acetous Mercurial Salt (69), and that which is formed by the Union of Mercury with the Acid of Tartar (70), are ſubject to a change of Colour from *White* to *Yellow*, by waſhing them with Water; by which means they are deprived of part of the Acid, in the ſame manner as the Nitrous and Vitriolic Salts.

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(68) Lemery's Courſe of Chym. c. 8. Red Precipitate. It retains a portion of Acid equal in weight to a ninth part of the Mercury.

(69) Traité de la Diſſol. des Metaux, par M. Monnet. p. 322. Ce ſel éprouve une ſorte de décompoſition par l'eau, à peu-près comme les ſels qui réſultent de la diſſolution du mercure par l'acide nitreux et l'acide vitriolique. En triturant le ſel, dont eſt ici queſtion, dans un mortier de marbre avec de l'eau chaud, *j'en ai enlevé peu-à-peu l'acide,* et l'ai converti en une poudre *jaune.*

(70) Ib. p. 325.

It appears, from theſe Experiments and Obſervations, that in proportion as the Acid Solvent is diſengaged from Mercury, the ſame Colours are conſtantly produced, and that their production is conformable to the ſame Law which, as has been already ſhewn, prevails in other ſubſtances. And it is indifferent, as to the change of Colours, which of the Acids are united to Mercury, or by what method thoſe Acids are extricated from it. (71)

Colours of Mercury calcined per ſe.

As all the abovementioned Mercurial Preparations become *Red*, whenever they are deprived of the

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(71) Exp. par M. Bayen, Fevrier, 1775, p. 156. Les chaux mercurielles que j'ai traitées, ſont au nombre de quatre; les deux premières ont été faites par l'intermède de l'acide nitreux, et de l'acide marin, et toutes deux ſéparées de ces acides par l'alkali fixe: l'acide nitreux ſeul a été employé dans la préparation de la troiſième; en fin la quatrième a été faite par la ſimple calcination.

Les procédés ont varié; mais les reſultats ont été les mêmes, et ces chaux, lorſq'elles ont été purgées de toute matière étrangère à leur état, ne diffèrent point eſſentiellement, l'une de l'autre,——*elles ont toutes la même intenſité de Couleur rouge.*

principal part of their Menſtruum; ſo Mercury calcined by Heat, without the Addition of any Acid, acquires the ſame Colour: and it is equal in brightneſs to that which is aſſumed by the Calces of that Metal, from which the Solvents have been expelled by Fire.

The Colour, however, of this Preparation is ſubject to Alteration from the Action of its Solvents: amongſt which, according to the Experiments of M. Margraf, the Phoſphoric Acid changes the *Red* to *Yellow* and *White*. (72)

I have not entered into the Conſideration of the Air, which Unites with Mercurial Calces, during their expoſure to the Fire; becauſe it does not relate to the greater or leſs Diviſion of their particles, which is the immediate Subject of my Inquiry. For the Colours, ariſing in this method of calcination, do not differ from thoſe which are produced by the Precipitation of the Metal from its Solvents; excepting in their ſuperior Brightneſs, of which the Cauſe has been already explained.

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(72) Opuſc. Chym. de M. Margraf, Diſſ. 1. p. 25. Joignons encore ici les rapports de l'acide du phoſphore avec quelques métaux et minéraux.——

Cet acide parôit auſſi agir en quelque maniere ſur la *chaux du mercure faite par lui même*, puiſque ſa couleur ſe change en *jaune*, et qu'il *blanchit*.

Amongſt the ſeveral coloured Preparations, which Mercury affords, few are capable of being employed in Painting; on account of their readineſs to undergo a Decompoſition, and of their Effects upon the other materials uſed in this Art.

Cinnabar is juſtly preferred to the others, as a Pigment: for the Sulphur, with which its particles are covered, ſerves as a Varniſh to defend it from the Action of the ſeveral Subſtances mixed with it in Painting.

As Cinnabar is inſoluble by any Menſtruum, I endeavoured to examine whether it would alſo reſiſt the Action of Iron when properly mixed with it: Sulphur, uncombined with Mercury, being ſubject to Decompoſition by that means.

(1.) To this End, I ground four ounces of Vermilion with half an ounce of Iron Filings, that the quantity of Sulphur in the maſs might be nearly equal to that of the Iron: and having moiſtened them with boiling water, I digeſted the whole in a gentle Heat, till it became dry by the Evaporation of the Water. No Decompoſition, or change, was produced by this Operation.

(2.) I mixed with ſeven parts of Vermilion, one part of Pruſſian Blue, and treated them as in the preceding proceſs. The latter ſubſtance was employed on account of the Inflammable Matter, and of the Earth of Alum, which are united with Iron, in its Compoſition. For each of theſe ingredients have alſo a ſtrong Affinity with the Vitriolic Acid (73). The Mixture, however, remained unaltered in this, as in the foregoing Experiment.

It appears from theſe circumſtances, that although Sulphur has a much greater Affinity with Iron, than with Mercury; and the Vitriolic Acid, in particular, has alſo a greater Affinity with Phlogiſton, and Aluminous Earth, than with the metallic part of the Cinnabar; yet the effects ariſing hence do not take place, except the maſs be expoſed to a conſiderable Heat.

Vermilion, therefore, may be conſidered as incapable of being impaired by the other Colours uſed in Painting, and of injuring them: and is the only known Preparation of Mercury, poſſeſſed of theſe qualities.

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(73) See the Note, p. lxix of the Preface.

*Colours of Mangan*eſe.

Amongſt the Mineral Subſtances, none affords a greater variety of bright Colours than Manganeſe, eſpecially when it is fuſed with Nitre, or with a Fixed Alcali.

This ſeems to have been firſt obſerved by Glauber, and afterwards by Pott, Cronſtedt, and other Mineralogiſts: but none of theſe writers have attempted to ſhew by what particular circumſtances the ſeveral colours were produced, or to explain them by any Rule of Optics.

I was, therefore, deſirous of examining whether the Changes of Colour, to which this Mineral is ſubject, do not ariſe from the ſame Cauſe, and obey the ſame Law, which appear to have prevailed in the other ſubſtances that I had already conſidered.

With this view I made the following Experiments: beginning with ſuch Liquors, as have the *leaſt* Power of *diſſolving* the Manganeſe prepared in the manner mentioned above, and proceeding with ſuch as are *ſtronger* Solvents of it.

(1.) Having put into a Glaſs a few grains of the Prepared Manganeſe, reduced to Power, I poured upon it *highly-rectified* Spirit of Wine. No Solution was produced by this means, and the Spirit remained tranſparent and *colourleſs.*

Oil of Turpentine was ſubſtituted in the place of Spirit of Wine, and the event was the ſame as in the foregoing Experiment.

(2.) To the ſame quantity of Prepared Manganeſe, common rectified Spirit of Wine was added, which immediately became *Yellow.* The Solution and Colour, thus effected, evidently ariſe from the ſuperabundant portion of Water, contained in this Spirit.

(3.) I poured *cold* Water, which had been carefully diſtilled, upon the ſame Mineral Preparation. The Water inſtantly acquired a vivid *Green.*

(4.) To the ſame Ingredient I applied diſtilled Water *moderately warmed:* by this management it aſſumed a *blue* Colour.

(5.) When *hotter Water* was uſed, it exhibited a *purple hue*.

(6.) Laſtly, when boiling Water was employed, it acquired a bright *Red*.

Thus, by means of the different degrees of power in the ſeveral Solvents, theſe Colours were produced in their regular priſmatic Order, viz. *Yellow*, *Green*, *Blue*, *Purple*, *Red*.

I ſhall add ſome further Remarks on theſe Experiments. In each of them the Colours, which I have mentioned, appeared inſtantly, upon pouring the Liquor into the Glaſs which contained the colouring matter: and it is to the firſt and immediate production of Colour in theſe mixtures that this deſcription is confined: for after a ſhort interval, Changes ſucceeded in ſome of them, which will be preſently explained.

In Exp. 1. I uſed highly-rectified Spirit of Wine, becauſe Fixed Alcaline Subſtances are inſoluble in that Liquor, unleſs a conſiderable Heat, or ſome intermediate ingredient, is applied. Oil of Turpentine alſo was employed, on account of the Difficulty of combining it with Fixed Alcali, under the preſent circumſtances: which is well known from the endeavours of Chymiſts to unite thoſe materials in the preparation of the Soap of Starkey. When Water was gradually dropped into the highly Rectified Spirit, it became at firſt *Yellow*, and afterwards dilute *Green*.

In Exp. 3, *cold Water*, which is a ſtronger Solvent of Fixed Alcali, than even the moſt phlegmatic Vinous Spirit, yields a vivid *Green*: but the colouring Matter is weakly held in Solution, for a great part of it ſoon falls to the bottom: and the portion, which then remains diſſolved in the Water, aſſumes a *bluer* or more *purple* hue on account of its greater *Attenuation*: for in this caſe fewer particles are diſperſed throughout the ſame quantity of Water. The Colours, which thus ſucceed the Green, are rendered ſomewhat obſcure and turbid, by the brown concretions which ſeparate from theſe Solutions, at the time that they become decompoſed.

As I found that the Solution in *cold Water* became Purple, when the colouring particles were more rarely diffuſed through it: I made the following Experiment, in order to determine whether a Green Solution might not be effected with *boiling Water*, by ſaturating it ſo fully, that the colouring matter diſſolved in it ſhould be in a very *denſe* ſtate. With this intent, I almoſt filled a ſmall Glaſs with the Prepared Manganeſe, reduced to powder, and poured upon it *boiling Water:* this inſtantly produced a bright *Green* Solution, which retained that Colour till all the Water had evaporated.

In Exp. 4, the *Blue* ariſing from the affuſion of warm Water, is much more dilute, and leſs vivid than the other Colours. Several ſimilar inſtances have already occurred, in the courſe of this Inquiry, in which the Blue, intervening between the other Colours in the midſt of the Order, was faint and imperfect; and ſometimes in its room a colourleſs Gap or Interval was found interpoſed, although the Yellow and Green, as well as the Purple and Red, which formed the Extremes of the ſame Order, were perfectly diſtinct and bright. (74)

It is ſcarcely neceſſary to obſerve that *warm* Water was uſed, on account of the ſuperior ſolvent Power which is always communicated to that Fluid by Heat, in proportion as it is increaſed.

The Purple tinge, which Glaſs receives from a ſmall quantity of Manganeſe, is ſimilar to that which is given to the hot Water in Exp. 5.

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(74) See p. 17, above.

In the ſixth Exp. the *Red,* produced by boiling Water, is much more permanent than any of the other Colours yielded by the cooler Liquors: from which circumſtance, as well as from the Colour, it appears that a more perfect Solution had taken place.

The change from Green or Blue, to Red, which is cauſed by Heat in theſe Experiments, is ſimilar to that which is produced in the Shells of Cray-fiſh and Lobſters, by the ſame means.

I have thus endeavoured to explain theſe Colours, which from the account given of them by Glauber, (75) and the ſubſequent writers, appeared extremely confuſed and irregular.

I alſo expoſed the Prepared Manganeſe to the action of Acids, Solutions of Neutral Salts, and various

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(75) Glauber. Profp. Germ. tranſlated by Packe, London, 1689, p. 353. "I ſaw that by mixing Magneſia with fixed nitre, it was by boiling them in a ſtrong crucible, opened by the nitre, from whence proceeded a delicate purple colour. I poured out the maſs and powdered it, and extracted it with hot Water, and paſſed the Liquor through a Filter, and then I had a purple fiery Liquor, which did almoſt every hour (ſtanding but only in the cold) change colour, ſo that it became one while green, then ſky colour, another while of a blood colour of its own accord, then again preſently it received other moſt elegant colours."

rious other Liquors: but it is ſufficient to obſerve, in general, that the Colours ſeem to be produced by them, according to their ſeveral ſolvent Powers. From theſe Experiments, I found that this ſubſtance affords a ready and uſeful method of examining ſeveral matters uſed in Chymiſtry, Medicine, and other Arts.

Thus the degree of Cauſticity of Volatile Alcalies may be determined by this Mineral Preparation, when it is incapable of being diſtinguiſhed by ſubjecting them to an Efferveſcence with Acids: for theſe ſhew the Preſence of Air, but not the Quantity of it. Both theſe circumſtances are diſcovered by the Prepared Manganeſe, which imparts to Spirit of Sal Ammoniac a bright *Red*; to a mixture of equal parts of Mild and Cauſtic Alcali, it communicates a *Yellow*, although this Liquor effervеſces with Acids; pure Cauſtic Alcali receives from it a vivid *Green*.

Theſe Colours vary conſiderably, in their Hue, from thoſe which have been already deſcribed: and from this difference, as well as from the Gradation of the colours, they appear to belong to a ſeparate Order.

this Inquiry, the Attenuation occaſioned by Heat ſhould have effected a contrary change of thoſe colours.

From theſe conſiderations, as well as from the Obſervations of M. Hellot, I judged that Heat, and Cold, are not neceſſary Agents in the Production or Suppreſſion of the Colour. With a view to a further examination of this matter, I made the following experiments.

(1.) The Colour of the Characters written with the Sympathetic Ink being produced, by warming the Paper on which they were drawn, I immediately expoſed thoſe coloured Characters to the Steam of boiling Water: taking care at the ſame time not to remove the Paper, which contained them, further from the Fire, than to the ſame diſtance at which it was held, when the Colour was brought forth. The Characters, thus expoſed to the Steam, preſently diſappeared: yet the Paper was not ſenſibly moiſtened.

(2.) I marked another Paper with the ſame Sympathetic Ink, and produced the Colour by warming it, as in the foregoing Experiment: in this ſtate I put it into a flint-glaſs Phial, which had previouſly been kept open for a conſiderable time, in a Sand-heat moderately warmed, that the moiſt Air might be expelled from out of it: I then ſtopped the Phial with a ground Stopple, which I ſurrounded with melted wax. The Paper, thus incloſed, was placed in various degrees of Cold: the Colour has, nevertheleſs, remained, ſome months, unaltered. I have ſince found that this ſecond Expriment is, in ſome reſpects, ſimilar to one made by M. Hellot.

The firſt of theſe Experiments, ſhews that the Colour of this Compoſition is capable of being deſtroyed, by a ſmall and inſenſible quantity of Moiſture, notwithſtanding, at the ſame time, the Paper be expoſed to a greater Heat than that which cauſed its appearance. From the ſecond Experiment, it is evident that mere Cold does not diſcharge or change the Colour.

From hence, and from the Obſervations of M. Hellot and M. Cadet, it appears that the Alterations are effected by the *Moiſture* of the Air, attracted by the Saline Matter when *cold*; and expelled from it when *heated*. And this is confirmed by the conſideration of the ready Deliqueſcence of the Salt, obtained from the Solution of Cobalt, of which the Ink is formed. M. Cadet attributes the Diſappearance of the Colour to a Fixed Alcali, communicated to the Compoſition by Sea Salt, or other Salts containing that Baſis. But this opinion is erroneous, becauſe Characters written with the pure Solution of Cobalt in the Nitrous Acid diluted, give a *red* Colour when heated, but become inviſible when removed into a cooler Air.

Coloured Salts, diſſolved in much Water, and ſpread, ſo as to form a thin layer of the Liquor, become pellucid and colourleſs. The cauſe of the loſs of Opacity and Colour by theſe means, is explained by Sir Iſaac Newton (78). Theſe Salts are again rendered viſible, as ſoon as the water, which held them in Solution, is diſengaged. I have already inſtanced Changes of Colour ariſing from an Evaporation of Water, whereby the Particles of the coloured Body accede, and are united into larger Maſſes. I ſhall hereafter relate another Experiment, in which one Subſtance affords ſeveral Colours, in their regular Order, by the gradual loſs of its Moiſture (79).

The preceding Experiments were made with Paper, marked with the Sympathetic Ink, in compliance with the common method of uſing that Liquor. But the operation may be much more diſtinctly obſerved, if a larger quantity of the Ink be evaporated,

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(78) See p. 29, above.——(79) See p. 91.

rated, in a veſſel not capable of imbibing it. When it is expoſed to a moderate Heat, in a white China Cup, and when the greater part of the Water is evaporated, the Saline Matter becomes *Green*. This colour ariſes from a ſuperfluous quantity of the Marine Acid, which ſoon flies off, and leaves the remaining part *Blue*, ſlightly inclining to Green. At the ſame time that it acquires this Colour, it forms a hard, dry Maſs, which, in a few minutes after its removal from the Fire, grows moiſt, and aſſumes a light *red* Colour. Theſe Alterations may be often renewed, by alternately heating and cooling the coloured matter: which does not again become green, after the ſuperfluous Marine Acid is once evaporated. But a drop of Spirit of Salt added to the *red* or *blue* Maſs, immediately renders it *green*.

The Change from *Red* to *Blue*, effected by *Heat*, in this Experiment, and the contrary Change which takes place on removing the matter from the Fire, are ſimilar to thoſe which the Characters written on Paper undergo: excepting only that the *red* Maſs, which is the Reſiduum of this greater quantity of the Liquor, affords ſo large a portion of the Saline Matter, that it cannot be rendered inviſible by the Moiſture, which it attracts from the Air. This circumſtance alſo is common to the Characters written on Paper, when, by neglecting ſufficiently to dilute the Solution, too great a quantity of the colouring Salt is ſpread upon the Paper.

When Preparations of Cobalt are acted upon merely by *Heat*, the Order of the Changes of Colour effected in them, is ſuch as, in other inſtances, conſtantly ariſes from that means of Attenuation. Thus when the *yellow* Solution of this Mineral, in the Marine Acid, is heated, it aſſumes a *green* Colour, paſſing from a leſs to a more refrangible colour. When this Solution is cooled, the *Yellow* is reſtored.

Colours changed by Dilution.

I have already examined ſeveral of the methods, by which the minute parts of bodies are ſeparated; ſuch as Heat, Solution, Putrefaction, &c. and have ſhewn that the Subſtances, affected by each of theſe means of Attenuation, conſtantly undergo regular Changes from the leſs to the more refrangible Colours of one Order, and from thence to thoſe of the Order of Colours next above.

I ſhall add to theſe, ſome inſtances of ſimilar Changes produced in coloured Liquors, by *Dilution:* which is another means of attenuating them. I have not met with any Accounts of Alterations of Colour, thus effected, except ſuch as relate to Orange Colours, which, by Dilution, are readily changed to Yellow. Some of theſe, from their intenſeneſs, incline to an obſcure Red. In theſe Experiments I have purpoſely avoided the Uſe of thoſe liquors, and have employed ſuch only as are capable of undergoing changes, from one diſtinct Colour, to others which are equally vivid and diſtinct.

(1.) I made a Tincture, by digeſting Turmeric, reduced to powder, in Rectified Spirit of Wine, till it had acquired a bright *Yellow* Colour. To one ounce of this, I added a few drops of a weak Solution of Potaſh, which changed the *Yellow* into a vivid Roſe-Colour.

Into this *red* Tincture I poured about an ounce of diſtilled Water; by which means it became Orange-coloured: to this I added another ounce of Water, which perfectly reſtored the original *Yellow* Colour of the Tincture.

Inſtead of Water, I poured Rectified Spirit of Wine into the *red* Tincture. The changes which it produced therein, were the ſame as were produced in the foregoing mixture. Laſtly, I ſubſtituted, in the room of the Water and of the Spirit, nearly a like quantity of the ſame Solution of Potaſh, by which I had given the red Colour in theſe mixtures. The red Tincture, diluted by this Alcaline Solution, underwent the ſame Changes as in the two former Caſes.

(2.) Strong Spirit of Nitre, drawn from rough Nitre much impregnated with inflammable matter, is of a full *Yellow* Colour: by the addition of diſtilled Water, it aſſumes a vivid *Green*. I learned this curious fact from Dr. Higgins, during my attendance on his inſtructive Chymical Lectures.

(3.) Another ſimilar inſtance of a Change from a leſs, to a more refrangible Colour, is afforded by the Nitrous Spirit, which is procured by Diſtillation from equal parts of Arſenic and Nitre: for its Colour is a bright *Green*, but it is inſtantly changed to a Sky Blue by the admixture of Water.

The colouring matter of both theſe Acid liquors ſeems to be Phlogiſton, from many circumſtances, and particularly from its flying off, and leaving the liquor colourleſs, when expoſed to the air in an open veſſel: and becauſe the Acid, drawn from pure Nitre, does not become green by the addition of Water: but the nitrous acid, however phlogiſticated in diſtillation or ſolution, is conſtantly thus affected.

(4.) To theſe Experiments, made by Dilution, I ſhall add another, which is effected by the gradual Evaporation of the Water intervening between the parts of a coloured Subſtance: by which operation they coaleſce, and are united into larger Maſſes, affording Colours in a regular Order, according to that Change of Texture.

I digeſted in Jamaica Rum, during ſeveral weeks, Gum Guaiacum reduced to powder. I added half a dram of this Tincture to an ounce of a thick liquid Mucilage, conſiſting of Gum Arabic diſſolved in Water. The Colour of this mixture was a *Sky Blue*: but when it had ceaſed to be fluid by the gradual Evaporation of the Water, it acquired a vivid *Green*:

when it was become ſo dry as to form a brittle Maſs, its Colour changed to *Yellow*.

I have thus examined the ſeveral means, by which the colouring parts of natural bodies are capable of being divided into ſmaller, or united into larger, Maſſes: and have ſhewn that each of theſe produces Changes of Colour, according to one uniform and general Rule.

It ſeems to me to be worthy of Obſervation, that as the Sky (which conſiſts of Air and Vapour, whoſe parts are more minutely divided, and more rarely diſſeminated, than thoſe of any other coloured Medium) is *Blue of the firſt Order*, which is the moſt refrangible Colour (80): ſo on the other hand, Gold, (which conſiſts of particles more denſely united, than thoſe of any other known Subſtance) whenever it is diveſted of its metallic Luſtre, is *Red*, which is the leaſt refrangible Colour. The Colours of the Orders, which intervene between theſe Extremes, are very numerous; but it appears from the foregoing Experiments, that all of them are regulated by the ſame Law.

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(80) See Newton's Optics, L. 2. part 3. prop. 7.

If the Simplicity and Uniformity, which Nature obſerves in her operations, is illuſtrated by this Inquiry, my purpoſe is fully anſwered. From the knowledge of the Cauſe, on which the Changes of Colour depend in Permanently coloured bodies, not only alterations which happen in their texture may be explained; but the Experiments and Obſervations may probably lead to curious and uſeful diſcoveries in the Arts of Painting, Dying, and various Manufactures, and throw new Lights upon many branches of Chymiſtry and Natural Philoſophy.

FINIS.

A

LETTER

To the RIGHT HONOURABLE

THE EARL OF MORTON,

Preſident of the ROYAL SOCIETY.

CONTAINING

EXPERIMENTS and OBSERVATIONS

ON THE

Agreement between the Specific Gravities of the ſeveral Metals,
and their Colours when united to Glaſs, as well
as thoſe of their other Preparations.

With ADDITIONS.

BY EDWARD DELAVAL, F.R.S.

Read at the ROYAL SOCIETY, Jan. 24, 1765.

ADVERTISEMENT.

THE following Paper was publiſhed in the Philoſophical Tranſactions for the year 1765, and the Author had the honour of receiving, for this Communication, the Medal which is annually conferred by the Royal Society. It is here added to the foregoing Work, on account of the Connexion between their Subjects. Their Relation to each other is, indeed, greater than it may probably appear to be, upon a tranſitory view. For, in one of theſe Inquiries the Colours, ariſing from a Difference of the *Size* of the colouring Particles, are examined: The other treats of the Difference of *Denſity*, and of the Colours produced by that Cauſe. If it be conſidered, however, that by ſeparating the Particles of a coloured Subſtance, they are removed to a greater diſtance from each other, ſo as to occupy more ſpace; it will thence be evident that the ſubſtance, thus affected, muſt undergo a *Diminution* of its *Specific Gravity*, at the ſame time that the *Size* of its Particles is *leſſened:* and the Converſe of this is likewiſe true.

My Lord,

I TAKE the liberty of laying before your Lordſhip the following paper, containing a variety of facts and experiments, which I have endeavoured to apply to ſome Optical inquiries.

Beſides the experiments originally contrived and made by myſelf, I have repeated moſt of thoſe which I have quoted from others.

Sir Iſaac Newton, in his Optics, has ſhewn by a ſeries of experiments, that the ſeveral differences of colours, exhibited by thin tranſparent plates, are occaſioned by their ſeveral thickneſſes; and that therefore the tranſparent parts of bodies do, according to their different ſizes, reflect rays of one colour and tranſmit thoſe of another; and conſequently that the bigneſs of the component particles of natural bodies may be conjectured from their colours; ſince the particles of thoſe bodies moſt probably exhibit the ſame colours as a plate of equal thickneſs, provided they have the ſame denſity. He concludes this whole doctrine in theſe words; "I have hitherto explained the powers of bodies "to reflect and refract, and ſhewed that thin tranſ-"parent plates, fibres, and particles, do, accord-"ing to their ſeveral *thickneſſes* and *denſities*, reflect "ſeveral ſorts of rays, and thereby appear of ſeveral "*colours*; and by conſequence, that nothing more "is requiſite, for producing all the *colours* of natural "bodies, than the ſeveral *ſizes* and *denſities* of their "tranſparent particles."

Though he has accurately ſhewn what *colours* ariſe from the ſeveral changes of *thickneſs*, I do not find that any one has attempted to explain *in what manner* the differences of *denſity*, in the component particles of bodies, contribute to produce the ſeveral differences of *colours*: and therefore I thought, that if inſtances could be produced of bodies whoſe ſeveral differences of *colour* appear to be proportioned to their ſeveral degrees of *denſity*, it would tend to illuſtrate this part of Optics.

To this purpoſe, however, are conducive all thoſe experiments and obſervations, from which Sir Iſaac Newton has inferred that bodies have their *refractive and reflective powers* nearly proportional to their *denſities*; and that the *leaſt refrangible* rays require the *greateſt* power to reflect them: which is deducible from hence, 1. That the *red* rays are reflected at the *greateſt* obliquity of incidence, and the *violet* at the *leaſt*. 2. That the *violet* is reflected, in like circumſtances, at the *leaſt* thickneſs of any thin plate or bubble, the *red* at the *greateſt* thickneſs, and the intermediate colours at intermediate thickneſſes. 3. The ſame appears from the table (p. 206.) in which the thickneſſes of air, water, and glaſs, and the colours produced by them are ſet down.

These experiments are applied by him to tranſparent bodies and the colours exhibited by them; but they are equally applicable to permanently coloured bodies: and it appears from them, that *denſer* ſubſtances ought, by their *greater reflective power*, in like circumſtances, to reflect the *leſs refrangible* rays, and that ſubſtances of *leſs denſity* ſhould reflect rays proportionably *more refrangible*, and thereby appear of ſeveral colours in the order of their denſity.

In confirmation of this reaſoning, I ſhall give inſtances of natural bodies, which differ from each other in *denſity*, though circumſtanced alike in other reſpects; and ſhall ſhew that they differ in *colour*, in the ſame order they do in *denſity*, the *denſeſt* being *red*, the next in *denſity*, *orange*, *yellow*, &c.

In ſuch an inquiry metallic bodies ſeem to deſerve our firſt and principal attention, as their *ſpecific gravities* have been aſcertained by well-known and repeated experiments. Without entering into a minute chemical theory of the principles of metals, it is ſufficient to obſerve that they are univerſally allowed to conſiſt of, 1. An inflammable matter, which is of the ſame kind in all the metals. 2. Of a fixed matter or calx, which appears in each of the metals to be ſpecifically different in *weight*, as well as in other properties.

As the inflammable matter, in the intire metals, acts ſtrongly on the rays of light, it is neceſſary to calcine, or to divide them into extremely minute particles, in order to examine ſeparately the action of the calx, or fixed matter, on the rays of light.

In order to examine all the metals in like circumſtances, by reducing them into the ſmalleſt particles, and depriving them of their Phlogiſton as far as was practicable, I expoſed each of them, united with a proper quantity of the pureſt Glaſs, *without any additional ingredient, to the greateſt degree of fire* they are capable of bearing, *without having all colour whatever deſtroyed.*

In this ſtate it appears, from a variety of experiments and facts, that they actually do, without any exception, exhibit Colours in the order of their Denſities, as follow,

Gold ——— Red.
Lead ——— Orange.
Silver ——— Yellow.
Copper —— Green.
Iron ——— Blue.

GOLD.

GOLD, which is the denſeſt of all the metals, imparts a red colour to *glaſs*, whenever it is divided into particles ſo minute, that it can be intimately mixed with the ingredients of which the glaſs is made; and it ſeems indifferent in what manner it is reduced to this ſtate. Thus:

1. From the powder obtained by rubbing *gold* with a pumice-ſtone, uſed by the goldſmiths in poliſhing it, mixed with nitre, borax, and potaſh, a beautiful *red* glaſs is produced [a].

2. When a ſmall quantity of a ſolution of *gold* in aqua regia is evaporated on a *glaſs* plate, with a gentle heat, that part of the *glaſs* on which it lay thinneſt,

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[a] Sol ſine veſte, cap. 8.

Junker, Conſpectus Chem. tab. XXXIII. de Auro, p. 852. *Aurum* detritum pumice, ſeu pulvis auri pumice, quo aurifabri ſua opera poliunt et abradunt, commiſtus, Gold-Schliff, ſi cum ana nitri, boracis, et cinerum clavellatorum liquido fundatur, præbet *vitrum*, inſtar optimi opificum encauſtici, *rubro colore* pellucidum, ſubſidentibus paucis auri granulis; teſtante autore Solis ſine veſte.

Shaw on Boerhaave's Chem. vol. i. p. 79. *Gold* ground with pumice, and afterwards fuſed with equal parts of nitre, borax, and pot aſhes, affords a fine tranſparent *red glaſs*.

neſt, is tinged *red*, by the entrance of the particles of *gold* into its ſurface [b].

3. Artificial rubies are made by mixing with *glaſs*, *gold* diſſolved in aqua regia, and afterwards calcined in the furnace [c].

4. Kunkel prepared a powder for the ſame purpoſe, by precipitating the *gold* from the ſolution by an alkaline liquor [d].

5. *Gold* precipitated by tin from aqua regia, and melted with *glaſs* in a proper proportion, tinges it with a beautiful ruby colour: this method was diſcovered by Caſſius [e], and farther improved by Kunkel [f].

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[b] Philoſ. Tranſ. N°. 286.

[c] Neri's art of *Glaſs*, chap. 129.

Calcine *Gold* with aqua regia many times, pouring the water upon it five or ſix times: then put this powder of Gold in earthen pans, to calcine in the furnace, till it becomes a *red* powder; which will not be in many days; then this powder, added in ſufficient quantity, and by little and little, to *fine cryſtal glaſs*, which has been often caſt into water, will make the tranſparent *red of a ruby*, as by experience is found.

[d] Lewis's Hiſtory of Gold, p. 176.

[e] Caſſius de Auro, p. 105.

[f] Junker, Conſp. Chem. tab. XXXIII. de Auro, p. 861.

6. The ſame colour is produced by fuſing *gold* with a large proportion of tin, and two thirds of lead, or by mixing it with regulus of antimony, or tin by calcination, and adding to *glaſs* the powders of *gold* obtained from theſe proceſſes [g].

7. *Gold* amalgamated with mercury, and digeſted with it for a conſiderable time, may be reduced to a ſubtile powder by expelling the mercury: this powder, melted into the *glaſs*, tinges it of a *beautiful red* [h].

8. *Gold leaf* melted into the ſurface of *glaſs*, by the electric force, imparts a *red colour* to it: this was firſt obſerved by Dr. Franklin, and has been often repeated [i].

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[g] Shaw's Notes on Boerhaave's Chem. vol. i. p. 78.

[h] Shaw's Abridgment of Boyle, vol. i. p. 459.
An induſtrious perſon, having united *Gold* with a particular quickſilver, kept them in digeſtion for ſome months; when the fire having been immoderately increaſed, the ſealed glaſs burſt with a frightful noiſe: though the upper parts were blown off and ſhattered to pieces, yet the lower eſcaped tolerably whole; and I took notice, with delight, that it was tinged throughout of a *fine and glorious red*, hardly to be matched by that of *Rubies*.

[i] Franklin's Letters on Electricity, p. 65.

There are many other ways of communicating this *colour to glaſs* by *Gold*; and I find no method by which it can be made to produce any other colour. If it be mixed in large maſſes, without being minutely divided, it imparts no colour to the glaſs, but remains in its metallic form.

Grummet attributes this colour to the manganeſe, uſed in making ſome ſorts of glaſs, the colour of which he ſuppoſes revivified by the nitre uſed in the preparation of the gold: it is neceſſary therefore to mention, that I have given a *red* by *gold* to ſeveral *glaſſes*, in the compoſition of which there was *no manganeſe*, and often by gold in the preparation of which there was *no nitre*.

Several preparations of *gold* will impart *a fine red* to the fritt or materials of which glaſs is made, in a ſmall degree of heat; though not minutely enough divided, or in too large quantity, to remain mixed with the glaſs, when expoſed to a degree of heat ſufficient to vitrify them perfectly.

LEAD.

LEAD, which is the metal whoſe *denſity* is next in order to that of Gold, affords a glaſs of the colour of the Hyacinth, a gem whoſe diſtinguiſhing character is, that it is *red* with an admixture of *yellow*, the ſame colour which by writers in optics is called *orange*.

1. Lead, kept in fuſion for a conſiderable time, in a ſtrong crucible and a very violent heat, is reduced to a glaſs of the colour of that gem [k].

2. Lead reduced to litharge, and melted with one third or fourth part of it's weight of ſand, in a covered crucible, in a ſtong fire for two or three hours, unites with the ſand into an *orange-coloured glaſs* like the former [l].

3. *Glaſs of Lead* is mentioned by ſeveral authors, as a compoſition proper, without the addition of any other ingredient, for imitating the *Hyacinth* [m].

SILVER.

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[k] Flora Saturnizans, chap. 11. Henckel de appropriatione, cap. ii. ſect. 4.

[l] Junker, Conſpect. Chem. tab. XIX. p. 434.
Recipe Lithargyrii partes tres, arenæ nitidæ partem unam; miſta imponantur forti tigillo; per 3 circiter horas tenuiſſime fundantur, quo facto maſſam fluentem in calidum mortarium effunde, et habebis *vitrum* pellucidum *Hyacinthini ferme coloris*.

[m] Shaw's Lectures, p. 299.
Lead melted into glaſs with ſand is the foundation of imitating all

SILVER.

YELLOW is the only colour which *ſilver*, the metal next to lead in *denſity*, can by any preparation be made to impart to *glaſs*.

1. Without inſiſting upon what ſome chymiſts affirm, that *ſilver*, on being calcined and expoſed to a violent fire for a long time, was partly reduced to a *yellow glaſs* [a];

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the coloured gems: for this glaſs itſelf will reſemble the Hyacinth, &c.

Merret's notes to Neri, chap. 61.

Our author mentions not a *Hyacinth* from *glaſs of Lead*. Bap. Porta ſupplies you with it, l. vi. c. 7. in theſe words: To make a very *Hyacinth*, and not much differing from the true one, put *lead* into earthen pots that are very hard, in a glaſs furnace, and there let it ſtand ſome days, and thus your *lead* is turned into *glaſs*, and imitates the *colour of the Hyacinth*.

Nichols's Hiſtory of precious ſtones, part i. chap. 7. of the Hyacinth.

The Hyacinth is a ſtone (as ſaith Boetius and Rulandus) which is *red* with a certain *yellowneſs*, or *rufeſcit in auro*; that is, it is *red* in *yellow*. Impoſtors adulterate it with a kind of *glaſs made of Lead*.

Boetii gemmarum et lapidum hiſtoria, l. ii. c. 31. Adulterium *Hyacinthi* vix meretur; in illius locum aliquando ſubſtituitur *ex plumbo vitrum*, quod a verâ gemmâ pondere et duritie facile diſtinguitur; mollius enim et gravius verâ gemmâ.

[a] Merret's Notes on Neri, chap. 82. Claveus ſaw *Silver* calcined two months in a glaſs furnace; the twelfth part of which became a *citron glaſs*.

2. I have often given *that colour*, by moiſtening the ſurface of the *glaſs* with a *ſolution of Silver*, and afterwards making it red hot.

3. If *Silver* be calcined with ſulphur, it readily communicates a *yellow colour* to glaſs [*].

4. Having carefully purified an ounce of *Silver*, I kept it in fuſion ſome hours, with a ſmall quantity of *glaſs*, and found, that the glaſs, when cold, had formed a beautiful *yellow enamel* on the ſurface of the *ſilver*.

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[*] Shaw's Abridg. of Boyle, vol. i. p. 458. To ſhew more particularly that glaſs is porous, we took *ſilver* calcined by burning *ſulphur* on it in the open air, and laid it upon a piece of *glaſs*, and placed it with the pigment uppermoſt, upon a few quick coals to neal a while; we gave it ſuch a heat as might make and keep it red hot, without fuſion; and then ſuffering it to cool by degrees, we found that the *glaſs* had acquired a *yellow and almoſt golden colour*.

Shaw's Abridg. of Boyle, vol. ii. p. 98. I learned from one of the chief artificers in painted glaſs, that thoſe of his trade colour it *yellow* with a preparation of a *calx of ſilver*.

Kunkel's Art of glaſs, part ii. art. 49. Experiment ſhews that it is from *Silver* the *fineſt yellow* is obtained. Shaw's Lectures, p. 316. A little *Silver* tinges white *glaſs yellow*.

Hook's Micrographia. obſ. 10. of Metalline colours. A third argument that the particles of metals are tranſparent is, that being calcined and melted with glaſs, they tinge the glaſs with tranſparent colours. Thus the *calx of ſilver* tinges the *glaſs* on which it is annealed with a *lovely yellow or gold colour*.

5. *Leaf ſilver* laid on red hot glaſs tinges it *yellow*.

When we meet with authors, who mention a blue or greeniſh colour communicated by ſilver, the cauſe muſt have been, that the ſilver uſed in ſuch proceſſes was mixed with *copper*, as it generally is, when it is not carefully purified [p]. I have always found, that *ſilver* purified by the *teſt* retained ſo much *copper*, that, when melted ſeveral times with nitre and borax, it imparted a *green tinge* at the firſt and ſecond melting, though afterwards *no ſuch colour* was obtainable from it.

COPPER.

GREEN is the only colour which *copper*, the metal next to ſilver in *denſity*, communicates to *glaſs*, when melted with it in a ſufficient heat, *without any additional ingredient*. Thus:

1. By grinding *cryſtal glaſs* in a *copper* mortar, and afterwards melting it, it becomes *green*.

2. *Copper* calcined *per ſe* in a furnace [q];

3. *Copper*

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[p] Merret's Notes on Neri, c. 90. Junker, Conſpect. Chem. tab. XXXIV. p. 889. 901. Shaw's Abridg. of Boyle, vol. ii. p. 98.

[q] Shaw's Abridg. Boyle, vol. ii. p. 98. Though *copper calcined per ſe* affords but a dark and baſely-coloured calx, yet the glaſs-men tinge their glaſs *green* therewith.

Neri,

3. *Copper* calcined with ſulphur [r]; and

4. Scales beaten off from red hot *copper* plates mixed with *glaſs*, equally impart a *green colour* to it.

It is indifferent in what manner the *copper* is prepared, in order to tinge the glaſs green, provided it be expoſed, *without any other ingredient*, to a ſufficient degree of heat [s]. I have frequently produced a *fine green* from *copper* filings unprepared.

If a quantity of *ſalts* be added in the preparation, they will, by attenuating the mixture, make the glaſs

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Neri, chap. 92. This ſort of *pureſt glaſs* will be tinged into all colours you deſire: for example, into an *emerald* with *braſs* thrice calcined, as is done for ordinary glaſs: into a ſea *green* with *braſs* calcined to redneſs.

[r] Junker, Conſ. Chem. tab. xix. p. 433. Beryllus marinæ *viriditatis* per *cuprum* cum ſulphure calcinatum.

[s] Kunkel's Notes on Neri, chap. 32. Though with *copper* alone one may produce *green*, it is nevertheleſs crocus martis differently prepared that makes a variety in it. I have not found that the different manners of preparing copper have produced different colours. I have experienced that by calcining *copper per ſe*, without any addition, I could produce all the effects that the author teaches us to bring about by different preparations of that metal.

incline to blue, the colour next in order[t]; but this happens only when the fire is moderate; for in a greater degree of heat, the redundant ſalts, even thoſe of the moſt fixed nature, are expelled[u].

It is true, that copper is mentioned by ſome writers, as an ingredient in *red* glaſs and enamel: but the *red*, which is the colour of the metal not diſſolved or mixed with the glaſs, remains only while the compoſition is expoſed to ſuch a degree of heat as is too ſmall to melt and incorporate it; for, if it be ſuffered to remain in the furnace *a few minutes after the copper* is added, the maſs will turn out *green* inſtead of *red*[w]: in effect, the preparation of

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[t] Flora Saturnizans, chap. xi. art. 6. When a green colour is to be given to glaſs, care muſt be taken *not* to uſe *too much ſalt* in the compoſition of the glaſs; otherwiſe the colour will be *blueiſh*, and bordering on the colour of the aigue marine.

Neri, chap. 32. An emerald colour in glaſs.

In making green you muſt obſerve that the metal have *not much ſalt*; with metal that hath much ſalt, as cryſtal and rochetta have, you cannot make a fair green, but only a ſea green; for the ſalt conſumes the green, and always inclines the colour to a blue; wherefore, when you would make *a fair green*, put *common metal*.

Shaw's Lectures, p. 29. Copper precipitated with common ſalt out of aqua fortis gives the torquois colour to white glaſs, when melted therewith.

[u] Kunkel's Remarks on Merret's Notes, p. 299.

[w] Neri, chap. 127. This chapter deſcribes the method of making red glaſs, in the compoſition of which copper is uſed; and Kunkel makes

of *copper* recommended on this occaſion, is exactly the ſame as that uſed in tinging *glaſs green.*

IRON.

IRON, being of all metals the moſt imperfect, is ſubject, by various means, to be calcined or reduced to a ruddy crocus, ſimilar to the ruſt that ariſes from it's being corroded by the acid in the air. In this ſtate, it requires a conſiderable degree of heat to diſſolve and incorporate it with glaſs: till that heat is applied, it retains it's ruddy colour; by increaſing the heat, it paſſes through the intermediate colours, till it arrives at it's *permanent* one, which is *blue:* this being effected in the ſame degree of heat in which we have examined the other metals, that is, *the greateſt that the glaſs will bear without loſing all colour whatever.*

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makes the following remark on it: "This compoſition is very difficult to make; it is neceſſary to ſeize the moment at which the matter is well tinged *red*, to take it immediately from the fire; for half a quarter of an hour too much is ſufficient to *change its colour.*" In the next chapter, ſpeaking of a *red* enamel, into the compoſition of which *copper* enters among other ingredients, Kunkel makes this remark: "This compoſition is very fine, and leſs troubleſome than the preceding one: but, after having added the *copper*, the matter muſt not be left on the fire: if this is not attended to, *it becomes green*, and the *red colour* that it had taken at firſt *does not laſt.*"

Gellert, Chem. Metallur. problem 97. *Copper* gives a blood-red to glaſs; but if it is left too long on the fire, *it becomes green.*

The green, with which the glaſs uſed for bottles and chemical veſſels is tinged, is occaſioned by the iron contained in the vegetable aſhes and ſand, of which that glaſs is compoſed. When the pots, in which the matter has been kept in fuſion, are nearly emptied, the glaſs remaining at the bottom is always *blue*; this is cauſed by it's continuing longeſt expoſed to the fire, and in ſo ſmall a quantity that the fire has a greater effect on it. The whole maſs acquires the *ſame colour*, if too much ſand be added in proportion to the aſhes; for, in that caſe, the materials being more difficult of fuſion, the workmen are obliged to apply a greater heat, and to continue it longer.

It is known, from the experiments of Lemery and others, that the vegetable aſhes contain iron[*]. To examine whether that metal be alſo contained in the ſand uſed in making this glaſs, and how far the colour of the glaſs depends upon it, I made the following experiments:

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[*] Becher, Phyſ. Subterran. p. 67.

Hæc prima terra (vegetabilis) cum mineralibus vitris, quæ ex arena et ſilicibus parantur, conveniens eſt, ut nulla re, niſi colore, inde diſcerni queat, qui *viridis* eſt, vel *ſubcæruleus*, indelibilem regni ſui aſteriſcum ſervans, nempe *vegetabilem viriditatem* exprimens.

Flora Sat. cap. 8. Note.

As that *blue or green* colour is owing to the *iron* which is found in the aſhes of all vegetables, it muſt not be looked on as a mark capable of characteriſing a vegetable earth.

Exp. 1. Having procured ſome of the ſand uſed in making green glaſs, I melted two parts of it with one part of borax, and one part of nitre, and found that it produced a glaſs ſimilar in colour to that which is made with the ſame ſand fluxed with pot-aſhes. From hence it appears, that the colouring matter was contained in the ſand.

Exp. 2. I mixed three parts of this ſand with one of powdered charcoal, and expoſed it for ſome hours to a red heat. When this mixture was cold, I ſeparated from it, by a magnet, ſmall grains of *iron*, weighing about one twentieth part of the ſand.

Exp. 3. I melted ſand thus *deprived of its iron*, with half its weight of borax and the ſame quantity of nitre, and found that it produced a perfectly *colourleſs* and tranſparent glaſs.

Exp. 4. To two parts of the white ſand uſed in making cryſtal glaſs, and one of borax and *nitre*, I added a twentieth part in weight, of the *grains of iron*, which I had extracted from the ſand by Exp. 2. and having vitrified this compoſition, I found that it was become exactly ſimilar in *colour*, to that commonly uſed in making green glaſs.

Exp. 5. I expoſed ſeveral pieces of *green bottle-glaſs* made at different glaſs-houſes, under a muffle, to a ſtrong fire, for the ſpace of half an hour, and found that they were all become *blue*.

If the crocus of iron is added in too great a proportion, it continues to adhere together, and remains unmixed, or at leaſt imperfectly mixed, with the glaſs, retaining for that reaſon the colour natural to it when undiſſolved; or if it be in a ſmaller quantity, though yet in too great a proportion to be diſſolved, it will make ſome intermediate colour between the *ruddy* and the *blue*, which laſt it always imparts, when in a ſufficient degree of fire and a proper proportion. The neceſſity of a due proportion of metal to the glaſs has been already inſtanced in gold, which, if in too large a proportion to be diſſolved by the glaſs, inſtead of imparting a red colour to it, runs together in its metallic form.

Henckel has given us a method of making a *beautiful blue glaſs* by this means. It conſiſts merely in mixing *iron* with the matter of which the *pureſt glaſs* is compoſed, and expoſing it to a *violent fire*.

Gellert obſerved alſo, that *iron* imparts to *glaſs* this colour[y]. Mr. Lehman obtained the ſame colour from emery, which is a kind of *iron ore*, or *ferruginous* ſtone, by mixing it with a vitrifiable earth; which colour he attributes to the *iron* contained in it[z].

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[y] Henckel, Diſſert. 6. On a *blue* obtained from *iron*.

I coloured glaſs with *iron*, and gave it a *very fine blue*. I had calcined, in a pot, fileings of Styrian *ſteel*, which I kept about a quarter of an hour in the fire, without ſtirring them, till they had taken a purple colour, bordering on violet; I mixed about half a grain, which I had ground well in a glaſs mortar, with fifteen grains of very white flint and a very fine alkali; I put the whole into a crucible, covered it with care, and expoſed it *to the moſt violent fire*. The furnace being cooled, I found *a glaſs* of the colour of a *ſapphire*; it was impoſſible to ſee a finer *blue*, either for colour or tranſparence.

Gellert. Chem. Metallurg. vol. ii. prob. 97. Cobalt calcined gives to glaſs a very fine blue; but if too much cobalt, for example an eighth part, is uſed, the glaſs will become black. The calx of *iron* produces the *ſame effect*; and ſometimes it happens that one ſide of the thin piece of glaſs is of the colour of *ruſt*, while the other ſide is *blue*.

[z] Lehman, Treatiſe on the formation of metals, p. 37.

As to the earth of cobalt, or biſmuth, which is the baſis of the blue colour, Henckel conſidered it as a *martial earth* in his Opuſc. miner. p. 573. Some experiments which I have made render that opinion very probable. I have obtained a *very fine blue colour* from a *ferruginous Spaniſh emery*: having once pulverized half a pound thereof and mixed it with an equal part of black flux, I melted this mixture in a well-covered crucible in a pretty violent fire: when the matter was melted, I flung in an inflammable ſubſtance: when that had intirely ceaſed burning, I emptied the crucible, and obtained a maſs of a *moſt beautiful ſapphirine blue*; but which, as one

Neri mentions a *ſky colour* imparted to glaſs by Bohemian granates, which method he conſtantly practiſed at a manufactory in Flanders[a]. It is well known that *iron* is the metal contained in thoſe ſtones; that they obey the load-ſtone[b]; and that, being calcined with a proper heat, they yield a conſiderable quantity of iron[c].

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may imagine, ſoon attracted the moiſture of the air: I repeated the experiment again without putting any black flux, and the colour became ſtill finer: but it was *remarkably beautiful* when the mixture was melted with a *vitrifiable earth.* I can attribute *this colour* only to the parts of *iron* contained in the emery.

[a] Neri, chap. 90. A curious perſon and practical chymiſt may extract a wonderful red from gold, from ſilver a *ſky colour*, and a much fairer from *granates* of Bohemia, which are low-priced; for, being ſmall, you may draw a tincture from them, as I have often done in Flanders.

[b] Boyle of gems, Shaw's Abridg. vol. iii. p. 107. Suſpecting, for ſeveral reaſons, that ſome *granates* contain, beſides other metalline ſubſtances, many corpuſcles of a *ferruginous nature*, I made choice of ſome ſmall ones, which, by their deep and almoſt dark colour, I gueſſed to participate largely of *iron* or *ſteel*, and applied them to a vigorous loadſtone, which, as I expected, took them up: and hereto they conſtantly adhered till they were forcibly ſeparated therefrom—ibid. vol. iii. p. 120. A *chalybeate* tincture obtained from granates.

[c] Junker, tab. x. p. 273. Multi *granati* minus pellucent; atque ex his vulgares præduri, atque alioquin igne indomiti, per ignem ſolarem grandibus vitris cauſticis collectum, denique in fluorem redacti ſunt, ac *merum ferrum* præbuere.

I expoſed in a crucible to a glaſs-houſe fire, for the ſpace of thirty hours, part of a flint glaſs retort, in which a native *green vitriol of iron* had been diſtilled, and which had been corroded and tinged by it; by this means it became coloured of a *fine tranſparent blue*, not diſtinguiſhable from that which cobalt imparts to glaſs.

Iron vitrified *per ſe* is converted into a blue glaſs [d].

In ſhort, it is indubitable that *iron is the only metal*, which will, *without any addition*, impart to the matter of glaſs *a blue colour*; for *copper* will not communicate that colour, *without the* addition of a conſiderable quantity *of ſalts*, or ſome other matter that attenuates it; and the other metals *cannot by any means* be made to produce it at all.

Having ſhewn that the *metals* exhibit colours, invariably in the order of their *denſities*, when melted with *glaſs* in a proper proportion, *without any other ingredient*, and *expoſed to a ſufficient heat*; I ſhall proceed to ſhew that the other preparations of the metals, viz. their ſolutions, precipitates, cryſtals, &c. do for the moſt part exhibit the ſame *colours*, in the order of their *denſities*, though not ſo invariably as their glaſſes; ſome ſmall variation of colour happening in the more imperfect metals, probably from a change of denſity in their different preparations.

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[d] Lewis's Courſe of Chem. p. 49. The ſpecific gravity of iron is to that of gold as 7,645 to 19,640. This metal requires a great degree of heat to melt it, when it throws out ſparkles, loſes conſiderably of its weight, and is at length converted into a *dark blue glaſs*.

GOLD.

GOLD precipitated from aqua regia, and waſhed with hot water, or boiled in a ſolution of alcaline ſalt, becomes *red* on being expoſed to a ſlight heat. Lewis, Hiſtory of gold, p. 108.

2. The ſame *colour* is produced when this precipitate of *gold* is ground with oil of vitriol, or ſpirit of ſulphur; or if it be mixed with ſulphur, and the ſulphur burnt away. Junker, tab. XXXIII. p. 859.

3. The ſmoaking ſpirit of Libavius, mixed with *gold* and afterwards drawn off from it by diſtillation, changes it's colour to *a blood red*.—Sol ſine veſte, exp. 19. Junker, tab. XXXIII. p. 861.

4. *Gold* is reduced into *a red powder*, by amalgamation with mercury, and expoſing it for a con-

ſiderable time to a ſlow heat.—Boyle's Abridg. vol. ii. p. 77. Junker, tab. xxxix. p. 987.

5. After the publication of this Paper, in the Philoſophical Tranſactions, Dr. Prieſtley made ſome curious Experiments on the manner of producing a Colour from Gold. I need not apologize for tranſcribing any part of them, except that which expreſſes too favourable an opinion of my Endeavours. It will appear, from the following paſſages, that Gold is capable of being diveſted of its metallic Luſtre, and of aſſuming a *red* Colour, by means of the Electric Exploſion, under circumſtances different from thoſe which attended Dr. Franklin's method of producing that effect, already referred to.

"I firſt procured a ſmall quantity of *grain Gold*, "which I was informed was the pureſt that the "goldſmiths know, and diſcharged an exploſion "of the battery through a train of the pieces, "an inch and a half in length, laid on a piece "of white paper. Only two of the larger grains "could be found after the Exploſion. Two "leaves of paper were burnt, or torn through "in ſeveral places, and more would probably "have been torn in the ſame manner, if I had

" uſed more. But what I principally attended " to was the tinge that was given to the paper, " with a view to which I had made the Experiment. The paper was ſtained near an inch " on each ſide of the train, with black inter-" mixed with *red*, making an odd motley appearance.

" The blackneſs in theſe tinges convinced me, " that there had been a calcination of ſome part " of the metal; but I was convinced it muſt " have been ſome alloy, by an Experiment I " preſently after made with a piece of *leaf gold*, " which, I believe, is generally the pureſt that " can be got. A ſmall ſlip of this I put through " a quill, letting a part hang out at each end; " and when I had made the diſcharge through " it, I found the quill tinged with a *beautiful* " *Vermillion* Red, without the leaſt intermixture " of black. When I diſperſed a ſlip of leaf " braſs in the ſame manner, the greater part of " the tinge was black, with a little brown mixed " with it in a few places.

" I make no doubt but that if I could avoid the " black duſt, in theſe Experiments, I could " make each of the metals give a tinge of its

"genuine colour, as they are excellently deſcrib-
"ed by Mr. Delaval in a late paper of the Philo-
"ſophical Tranſactions [*]."

It appears, from theſe Experiments, that Gold acquires a *red* Colour, by a minute Diviſion of its Particles, without any addition.

6. If ſix parts of antimony are fuſed with one of *gold*, and the antimony driven off by the blaſt, a *red* powder of *gold* is left behind.—Caſſius de Auro, cap. 10.

7. *If gold leaf* be cemented and ground with decrepitated ſalt, hartſhorn, pumice, or chalk, and expoſed to a proper heat, *the metal becomes red*, and may be precipitated from a ſolution of thoſe ſubſtances in a *red* powder.—Junker, tab. XXXIII. p. 854. Lewis's Hiſtory of gold, p. 74. Sol ſine veſte, cap. 6.

8. A *red* tincture may be prepared from *gold* by ſeveral methods mentioned by Libavius, Alchem. lib. ii. p. 130. Junker, tab. XXXIII. p. 868.

9. A ſolution of *gold* in aqua regia prepared from ſal ammoniac may be ſublimed of a *blood red* colour.

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[*] Hiſtory of Electricity, p. 682.

The ſame is effected by diſſolving the calx, or crocus of *gold*, in other menſtrua. Lewis's Hiſtory of gold, p. 100. Junker, tab. xxxiii, p. 857.

10. A ſolution of *gold* in aqua regia, evaporated properly, affords cryſtals of a *bright red* colour.—Caſſius de Auro, p. 109. Junker, tab. xxxiii, p. 862. 868. Lewis's Hiſtory of gold, p. 99.

11. *Aurum fulminans* moiſtened with water, has been found to tinge gems deeply of a *fine red.* Phil. Tranſ. N°. 179.

12. A ſolution of gold tinges ivory, cotton, the ſkin, and other ſubſtances *red.*

Rubies being frequently found in *gold mines*, it is very probable that they receive their colour from that metal; and from this circumſtance, before the experiment had been made, Libavius rightly conjectured that a ſolution of *gold* would communicate a *ruby* colour to *glaſs*. Libavii Alch. p. 88.

It does not appear that, excepting the colour natural to *gold* in its intire ſtate, any other than *red* can be obtained from preparations of this metal: it is from this colour, which *gold* aſſumes whenever its metallic brightneſs is deſtroyed, that writers in chymiſtry call it leo *ruber* [f].

LEAD

THE only coloured preparations of *lead*, (beſides its glaſs) are thoſe produced by calcination in the furnace. The firſt of the primary colours produced by this proceſs is yellow, the calx paſſing from that colour through *orange* into red.

This variety of the Colours proceeds from the Imperfection of the Metal. It is probable that, during the Calcination, Lead receives a ſmall portion of Phlogiſton, as well as Air. For the Affinity between the Earth of this metal and inflammable matter is very great: as appears from the readineſs with which its Solutions and Calces unite with Phlogiſtic Vapours. The effect of ſuch an Union muſt, probably, be a Change of Colour from Orange to Red. For Sir Iſaac Newton has ſhewn that Bodies reflect more ſtrongly, in proportion as they poſſeſs more Phlogiſton: and that the leſs refrangible Colours require a greater power to reflect them. The perfect metals gold, and ſilver, not being capable of loſing any of their Phlogiſton, or of receiving an additional quantity of it, are not liable to a Change of Colour by this means.

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[f] Libavius de natura metallorum, lib. i. cap. 4. de auro. In ſuo manifeſto citrinum eſt, in occulto ſummam continet *rubedinem*; unde et non tantum tinctum ipſum eſt, ſed et tincturam *rubedinis* confert abundantem.

Dum *citrinum* dicitur, externus vultus qualis eſt poſt excoctionem reſpicitur: illa tamen citrinitas igne cæmenti et in opere philoſophico ſumma *rubedine* permutatur. Itaque hinc eſt philoſophorum axioma, quod in *citrinitate* lateat *rubedo* excellentiſſima, qualis eſt *rubini* gemmæ.

Voces occultum, manifeſtum, non ita pueriliter ſunt accipiendæ, quaſi in ſuperficie ſit flavum, in centro *rubrum:* ſed progreſſiones colorum in perfectione artificiali notantur, quod naturali proclivitate et diſpoſitione poſt citrinitatem abolitam, aſſumat *rubedinem*.

Leo ruber non ſolet vocari, antequam ab arte eleboratum, et aſtrale, ut aiunt, factum. Potentia tamen etiam ſimplex et naturale aurum ita vocare non eſt abſurdum, cujus *tinctura* appellatur ejus ſanguis, quo vocabulo et *fermentum rubeum* denotatur.

SILVER.

THE Preparations of Silver, which are of a primary Colour, (beſides the Yellow which this metal imparts to glaſs, and other vitreous ſubſtances, as Earths, or Salts) are Luna Cornea, which Mr. Boyle ſays is of a *fair Yellow*[t], and ſome of its Precipitates

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[t] Shaw's Boyle, vol. i. p. 255. Phyſical Eſſays, Edinburgh, 1754, vol. i. p. 310. Art. 10. Remarks on chymical ſolutions and precipitations, by A. Plummer, M. D.

When either a muria of ſea ſalt, a ſolution of ſalt ammoniac, or ſpirit of ſea ſalt (for theſe three have nearly the ſame effects) is put into tates from a Solution in the nitrous Acid, eſpecially thoſe which are obtained by means of Salts impregnated with inflammable matter [h].

Dr. Prieſtley reduced Silver to a *Yellow* matter, by the electric Exploſion, as appears from the following

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into a *ſolution of ſilver*; it becomes milky, and, as it were, curdled, and at length a white powder ſubſides to the bottom: this powder being waſhed with warm water and dried, is ſoft and impalpable; it's weight exceeds that of the ſilver diſſolved by more than one fixth part. This powder comes much ſooner to fuſion than ſilver, but does not recover the appearance or properties of that metal; for it looks like a piece of *yellowiſh glaſs*, ſemiopaque and brittle, yet bending or yielding a little, whence it gets the name of luna cornea.

[h] Margraf. Opuſc. Chym. Diſ. 5. § vii. J'ai diſſous demi-once d'argent le plus pur, dans une ſuffiſante quantité d'acide nitreux, le mieux épuré:—j'ai pareillement diſſous dans quatre parties d'eau diſtillée une once de ſel d'urine, que j'ai dit plus haut faire la baſe du phoſphore. J'ai verſé par gouttes cette ſolution ſaline ſur la ſolution ſuſdite d'Argent, étendue dans trois ou quatre parties d'eau; et j'ai fait cette inſtillation à diverſes repriſes, juſqu'à ce qu'il ne ſe précipitât plus rien. Il ſe trouve au fond un précipité *de la plus belle couleur de Citron*.

Mem. de Chimie. par M. Sage, Paris, 1773, p. 93. J'ai reconnu que l'acide marin éprouvoit une modification particulière, lorſqu'on le diſtilloit avec des matières huileuſes.—L'acide marin qu'on obtient en le diſtillant ainſi, eſt beaucoup plus ſubtil; il forme avec l'alkali fixe, un ſel fébrifuge cubique, et avec l'alkali volatil, un ſel ammoniac; maiſ ces deux combinaiſons ſalines diffèrent du ſel fébrifuge et du ſel ammoniac ordinaires, en ce qu'elles ont la propriété de *précipiter en jaune citrin l'Argent* diſſout dans l'acide nitreux.

lowing paſſage[1]: "With the ſame view, I laid a "ſimilar train of bits cut with a knife from a piece "of as pure *Silver* as I could procure. They were "diſperſed, and the paper burnt through, in the "ſame manner as with the gold; and the ſpace of "about an inch on each ſide of the train was ſtained "with black intermixed with a deep *Yellow*, which "was conſiderably different from the tinge made by "the fuſion of the gold.

"The blackneſs in theſe tinges convinced me, "that there had been a calcination of ſome part of "the metal; but I was convinced it muſt have been "ſome alloy, by an Experiment I preſently after "made with a piece of leaf gold."

COPPER and IRON.

IT thus appears that all the preparations of *gold*, and *ſilver*, invariably retain the *colours* peculiar to the *order* of their *denſities*, and that they are the *ſame with thoſe which they communicate to glaſs*.

The two moſt imperfect metals, copper and iron, being very eaſily acted on by almoſt all menſtrua, the colours of their ſolutions, &c. viz. green and blue, are apt to change into each other's order; the copper in ſome ſolvents becoming blue and the

iron

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[1] Hiſtory of Electricity, p. 683.

iron green, and in other ſolvents vice verſa; this probably depending on the increaſe or diminution of their denſities.

The ſolutions of copper, in the acids of nitre and ſea ſalt, and in the vegetable acids, are green. But if copper be attenuated by ſolution in volatile alcalies, it becomes blue. Theophraſtus and others have obſerved, that *emeralds* are frequently found in *copper mines*; and it is probable that they obtain their tinge from that metal.

I melted ſome *emeralds* with twice their weight of ſalts, and found that they had formed a fine *green glaſs*, ſuch as would have been produced from the ſame quantity of a *vitrifiable earth*, and about a hundredth part of its weight of *copper*.

Iron diſſolved by the vitriolic acid is green; but if further attenuated by a chemical proceſs, it produces that beautiful colour called *Pruſſian blue*. Phil. Tranſ. N°. 38. Henckel Diſſert. 6. The Blue martial earth, called by Cronſtedt native Pruſſian Blue [k], ſeems to be of the ſame kind as that which is found in Peat Moſſes in Scotland. It owes its Colour to the Iron, which enters into its compoſition [1]. I think it probable that this Blue is produced by an admixture of Aſtringent Vegetables, with the Vitriol which is often found in Peat and Turf; in ſome places, as in the Beauvaiſis, that Salt abounds in the Turf ſo conſiderably, that ſeveral Manufactures for the extraction of it are eſtabliſhed there.

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[k] Cronſtedt Syſt. Miner. Sect. CCVIII. Iron, with an alcali and phlogiſton. Calx martialis phlogiſto juncta, et alcali precipitata. Blue martial earth. Native Pruſſian Blue.

A ſimilar *blue* may be obtained from the *iron* contained in the aſhes of all plants. Henckel, Flor. ſat. chap. 8. parag. 55.

Having

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(1) Looſe or powdery, found among the Turf in the levels of the province of Skone: Alſo in Weiſſenfels, and at Norvlanden in Norway, &c.

[1] Mem. de Chimie. par M. Sage, p. 65.—Les acides minéraux enlèvent tres-promptement la couleur du *Bleu de Pruſſe natif*, on trouve alors au fond du Vaſe, *une terre martiale* brunatre; l'acide nitreux diſſout ce méme Bleu de Pruſſe natif, avec efferveſcence. Il réſulte de ces expériences, que le principe colorant eſt beaucoup moins inhérent dans le Bleu de Pruſſe natif que dans celui que nous devons à l'art, puiſque les acides avivent la couleur de ce dernier loin de l'altérer.

Le Bleu de Pruſſe natif, mis en digeſtion dans les alkalis étendus d'eau, perd ſa couleur; on trouve au fond du vaſe de la *terre martiale brune*; lorſque les alkalis ſont ſaturés de l'acide qui donne la couleur au bleu de Pruſſe natif, ils ne font plus efferveſcence avec les acides: ces mêmes alkalis ſont propres à précipiter de ſa diſſolution, le *Fer* en très-beau Bleu de Pruſſe.

Having expoſed a pound of wood aſhes in a luted crucible, to a pretty ſtrong fire, for thirty hours, the greateſt part of them became tinged *blue* by the *iron* contained in them.

A *blue* may be alſo extracted from a *martial vitriol*, by ſpirit of wine. Henckel, de appropriatione, chap. 2. parag. 257.

An inſtance of a mineral ſubſtance changing it's colour from *green* to *blue* on it's *ſpecific gravity* being *diminiſhed*, appears in a ſtone deſcribed by Dr. Grew in the Muſeum of the Royal Society: this gem is a kind of *emerald*, which, when *expanded* by heat, becomes *blue*, and remains of that colour till *cold*, in which ſtate it returns to it's uſual colour, which is *green*.

Tin is not capable of being vitrified, or imparting any colour, except an opake white, to glaſs; nor are any preparations of it of any primary colour.

MERCURY.

THERE is no body of an intermediate *weight* between *gold* and *mercury*: and it is probable that a great part of the difference between their ſpecific gravities depends on the *fluidity* of the one and the *ſolidity* of the other.

Mercury is not capable of communicating any colour to *glaſs*, being ſo volatile that it will not bear the degree of heat neceſſary to incorporate it with the glaſs in fuſion.

But it is well known that it's *calx*, either prepared *per ſe*, or by diſſolving it in an acid and evaporating the menſtruum, is *red*.

2. A ſolution of mercury tinges the ſkin, &c. *red*, as *gold* does.

PLATINA.

THE *ſpecific gravity* of *platina* being nearly equal to that of *gold*, it ſeems neceſſary to examine whether the colour of it's preparations correſpond with thoſe of gold.

On looking into a diſſertation written by Dr. Lewis on that metal, in the Philoſ. Tranſ. I find that the *precipitates* and *cryſtals* obtained from ſolutions of *platina* are *red:* and that a ſolution of that metal in aqua regia, to perfect ſaturation, is of a *dark red*, though, when diluted, *yellow*; in the ſame manner that "a *red* liquor (as Sir Iſaac Newton obſerves) in a *conical glaſs*, looks of a pale and dilute *yellow*, at the bottom, where it is thin; and a

"little

their contact with the air, aſſume the colour peculiar to its ſalt or vitriol.

Moſt vegetables, when they grow in ſuch a manner as to be defended from the contact of the air, are prevented from becoming green.

This happens to the roots of trees, and as much of their ſtem as is covered with earth: graſs growing under ſtones, or other bodies, that accidentally lie on it, is white; not having the leaſt green, but as the air has acceſs to it: and it is a method commonly uſed by gardeners, to cover with earth thoſe parts of plants which they would preſerve white: by that means hindering them from being tinged green by the contact of the air, as the parts expoſed to it are: though it appears from experiment that the preſence of light, as well as of air, is neceſſary to the production of the colour of plants.

Beſides the *iron* diſſolved at the *ſurface* of plants by the air, that which is contained in the *inſide* of them, may be kept in a ſtate of ſolution, when it meets with a proper quantity of *acid*; and it is remarkable that the inſide of moſt fruits and other parts of plants remain *green* no longer than they continue in an *acid* ſtate.

The quantity of *iron* contained in plants will not appear too ſmall to produce their colour, when it is known that one grain of vitriol, of which only a ſmall part is iron, the reſt being acid and water, is able ſenſibly to communicate a *green colour* to ten thouſand grains of water. Lemery mentions this great diviſibility of iron as an argument of its being able to paſs into the ſmalleſt parts of plants. Mem. Acad. anno 1706.

A circumſtance which ſtrongly confirms that the *colouring matter of vegetables*, and a *ferruginous vitriolic ſubſtance*, are of one and the ſame kind, is, that the *vitriol of iron*, which is *green*, paſſes through the ſame colours, while its moiſture is evaporating, which *vegetables* do, when by withering they undergo the ſame ſort of change: the *vitriol* deprived of its water by calcination grows firſt *yellow* and then *red*[*]; and Sir Iſaac Newton has obſerved that, “ when *vegetables wither*, ſome of them turn to a “ *greeniſh yellow*, and others to a more perfect *yellow* “ or *orange*, or perhaps to *red*, paſſing firſt through “ the aforeſaid intermediate colours: which changes

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[*] Boerhaave's Chym. vol. ii. proceſs 164. If this ſecond calx (that is, *green vitriol* reduced to powder by a moderate heat) be calcined in a crucible, in an open ſtrong fire, it grows *yellow*, *red*; and at length becomes a deep purple powder.

"ſeem to be effected by the exhaling of the moiſture, "which may leave the tinging corpuſcles *more denſe* "and ſomething augmented by the accretion of the "oily and earthy parts of that moiſture." Newton's Optics, lib. ii. prop 7.

This is the only paſſage in Newton, in which he inſtances any *permanent colour* of a natural body as ariſing from a *change of denſity*: and though he has not any where at large delivered his opinion on this ſubject; it appears that, in this caſe, he conſidered the *leſs refrangible colours* in withered vegetables as ariſing from their *increaſe of denſity*; which is what I endeavoured in the beginning of this paper to prove deducible from his doctrines.

I am,

My Lord,

Your Lordſhip's

moſt obedient

and moſt humble Servant,

Old Palace-Yard,
Jan. 17, 1765.

Edward Delaval.

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